GEOLOGICAL SURVEY OF CANADA.

SIR W. E. LOGAN, F. R. S., DIRECTOR.

FIGURES AND DESCRIPTIONS

OF

CANADIAN ORGANIC REMAINS.

DECADE I. — IV

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NOTICE.

In the preface to Decade III., already published, the reason has been given why the present one, though second in time, is first in number. In the same preface it has been stated that the present Decade, confided for the descriptions to Mr. J. W. Salter, palæontologist to the Geological Survey of the United Kingdom, is intended to illustrate a commingling of forms heretofore supposed to belong to distinct epochs; that the drawings are by Mr. Bone, and the engravings by Mr. Sowerby, artists well known for their accuracy and skill.

W. E. LOGAN.

Montreal, 11th April, 1859.

PREFACE.

In describing the few generic types given in these pages, I am acting as pioneer for my friend Mr. E. Billings, who wishes me to share this portion of his task, and I very willingly join with him, and with Professor James Hall, in commencing this series of Decades. The drawings and plates have been executed for some time past.

In a short memoir on the fossils collected in the limestone at Pauquette's Rapids, on the Ottawa River, which was presented to the British Association in the year 1851, and appended to Sir William Logan's paper on the Rocks of Canada, it was stated, that the limestone included fossils characteristic of all the lower divisions of the New York system, from the Calciferous sandrock to the Trenton limestone inclusive. With regard to the lowest of these strata, a correction may be made, for, when more closely examined, the *Euomphalus uniangulatus* of that rock appears to be somewhat different from the Ottawa shell referred to it. The other limestones are certainly represented;—the Chazy by the peculiar genus *Maclurea*, and the Birdseye and Black-river limestones by some identical corals and shells. With the Trenton formation, as might be expected, the affinity is greatest; and the beautifully preserved fossils, silicified in a pure calcareous matrix, and weathered extensively, permit of accurate comparison with the figures and descriptions of those from the United States.

In this collection from a single calcareous band, we meet with the *Bellerophon sulcatinus* and *B. rotundatus* of the Chazy limestone; *Murchisonia ventricosa* and the *Stromatocerium* from the Birdseye.

There are Black-river limestone species, viz., *Columnaria alveolata*, and the remarkable cephalopod, *Gonioceras anceps*, of Hall. Of Trenton species, we have in abundance the *Strophomena filitexta*, *Pentamerus* (*atrypa*) *hemiplicatus* and *Atrypa increbescens*, *Murchisonia gracilis* and *M. bicincta*, *Cyrtoceras annulatum* and *C. lamellosum* of Hall (*C. Billingsii* of this Decade), *Orthoceras arcuoliratum*, *bilineatum* and *laqueatum* of Hall, together with *Ormoceras tenuifilum*, a fossil common to both the Trenton and Black-river limestones. *Schizocrinus nodosus* is the common Crinoid, and species of *Petraia* (*Streptelasma*), with *Favosites lycoperdon*, go to swell the list of Trenton species. Lastly, there is the characteristic *Asaphus gigas*, so that the parallel is complete.

J. W. SALTER.

CANADIAN ORGANIC REMAINS.

Maclurea Logani, Salter.

Decade I. Plate I.

Generic character.—Maclurea, Lesueur. Mollusca Nucleobranchiata. Family Atlantidæ? "Shell discoidal, few whorled, reversed* (the apical whorls being brought down to the base and the umbilicus flattened out); upper surface convex, deeply perforate instead of raised into a spire; outer side spirally grooved; operculum sinistrally sub-spiral, solid, with two internal projections for the attachment of muscles—one of them beneath the nucleus, and very thick and rugose."—Woodward.

Synonyms.—M. Logani, Salter, in Rep. Brit. Assoc., 1851, Trans. Sections, page 63; in Murchison's "Siluria," 3rd edit., 1859, page 215, figure 1 (?) and 1*a*, operculum.

Diagnosis.—M. 3½ *uncias lata, paucispirata*; *anfractibus* 4-5 *(ultimo in latitudine præcedentem ter superante), subtus planissimis lævigatis, et ad latera multistriatis insuper, valde convexis, umbilico parvo.*

This fine species, detected in great plenty by the officers of the Survey in exploring the Ottawa river, was first noticed in Sir R. I. Murchison's paper on the Silurian Rocks of the South-west of Scotland, in the Quarterly Journal of the Geological Society, vol. vii., 1851, page 176, and its name proposed in the British Association Reports for the same year.

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* The reader will please to bear in mind, that though drawn uppermost on the plate (a position which shews the characters best), the flat spiral side of the whorls is really to be considered the base, and the umbilicus the upper side. See Woodward's Manual of Shells, p. 202, where the shell is represented (fig. 106) in its normal position.

It is clearly distinct from, though closely allied to, the great *Maclurea magna* of the Chazy limestone, which may be seen so often in the paving-slabs and door-ways of New York, and which has been well figured by James Hall.

The genus is by no means rare in the old deposits of the Silurian seas, and apparently there were several very distinct species, some of which are yet unpublished, and one, *M. Peachii* (Salter), which has the operculum extravagantly elongated and curved, occurs in plenty in a rock very like the Canadian limestone, and full of similar types, in the north-west angle of Scotland. It has been figured, and its locality described, by Sir R. I. Murchison, in the Quarterly Journal Geological Society for 1858. Another is plentiful in the Llandeilo limestones of the south of Scotland.

Description.—*M. Logani*, when perfect, is fully three and a half inches wide, and is conspicuous for the great flatness of its lower or whorled side, and the fewness of its whorls, for, if we except one or two minute inner ones, there are but two or three distinct whorls, which diminish so rapidly in breadth that the outer is at least thrice the width of the preceding ones in succession, and greater than that of all the inner whorls taken collectively: in *M. magna* it is greatly less than these. The whorls are very gently convex between the sutures, which are sharply marked though not deep, and are closely striated by regular sharp-arched lines of growth. The sides of the whorl are steep, pyramidal, the depth exceeding the width of the whorl, and are furrowed by a number of deep grooves, sometimes 16 or 17, a few of which are interlined with smaller ones. Occasionally seven or eight only are present, or a deep one (figure 3) occurs at a short interval; but this may be the result of injury.

The base itself is smooth, or with faint concentric striæ only, and the umbilicus* rather abrupt and very narrow, not above one third the width of the whorl, and with a rounded edge. The shell is solid, nearly a line thick.

The most singular part of the shell is its operculum, sometimes fixed, as in figure 3, in its normal position, at other times drawn within the shell. It is exceedingly solid, the successive layers are subspirally arranged, tiling over one another, and are antiquated in growth. The nucleus is near the inner and lower angle of the mouth; in old shells it is pushed further out, and becomes the apex of a very solid short cone, one face of which lies close upon the inner flat

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* Used in a false sense, since it is the perforate spire.

surface of the whorl. Two curved furrows radiating from the nucleus divide the surface into three areæ, less distinct in the mature shell. Inside, a thick compressed process *(a)* takes its rise beneath the nucleus, retaining its place near the inner angle of the mouth, even in the adult shell, when the nucleus itself has removed further out (figure 6). The process is as broad as long, and on its oblique free margin it is roughened and grooved for the attachment of muscles. Another attachment, similar but much less prominent, exists at the inner and upper angle *(b)*, and a line of minute prominences partially connects the two.

These processes have their analogues in the internal ridges of the operculum in *Nerita* and some other genera, and in that of the small Pteropod shell, *McGillivrayia* (Forbes), but no recent shells are known in which they are equally produced.

The view above expressed of the shell being a reversed one in which the spire is deeply sunk, in the so-called umbilicus, and the latter expanded and flattened so as to appear like the upper side in ordinary shells, will not appear unlikely, if comparison be made with *Ophileta* (plate 3), in which there is a similar condition of the spire.

Moreover, this view has the advantage of rendering it unnecessary to suppose an operculum arranged on a different plan to that of ordinary univalves, since no case is known in which the nucleus is placed at the upper angle of the mouth, though some few have it external. The genus *Atalanta* however, says M. Woodward, has the spire and the operculum both sinistral; hence it is possible that *Maclurea* might be an opposite case, in which it is dextral in both.

The alliance of this heavy shell with the lighter and fragile Nucleobranchs would seem much more unlikely, had we not such solid forms as *Bellerophon* to compare it with. But there are no other genera with which it can be better associated, since *Euomphalus* has quite a different operculum (multispiral), and no opercula are known in *Ophileta* or *Raphistoma*, depressed forms resembling *Maclurea*, but which are probably, with *Murchisonia*, members of the families Ianthinidæ or Trochidæ (see plates 2, 3). Prof. Forbes believed there was some affinity between *Maclurea* and *McGillivrayia*, above mentioned, a minute spiral Pteropod with the nucleus of the operculum external, and with a process beneath it. But this affinity is not so close as that suggested by *Bellerophon* with the Nucleobranchs, and we must therefore leave it for the present where the judgment of Mr. Woodward has placed it, and regard *Maclurea* as a Heteropod with a heavy shell, and probably stationary or nearly so on the bottom, seeing that its

upper or convex side is constantly overgrown with sponge (*Stromatocerium rugosum**), while the flat or lower side preserves the sharp lines of growth, which would have been abraded had the animal been endowed with much locomotion.

Raphistoma, Helicotoma, and Ophileta.

Decade I. Plates II. and III.

Genus *Scalites*, Conrad. Mollusca Gasteropoda. Family Ianthinidæ. Shell thin, turbinate or depressed, with angular whorls, flat above; aperture deeply notched, but without a band.

Sub-genus *Scalites*. Turbinate; whorls flat above, turrited, produced below; umbilicus none. Form elongate.

Sub-genus *Raphistoma*, Hall. Depressed, often discoid; spire flat, or only gently convex, with close sutures; whorls acute angular externally, and often with an angular edge to the moderate umbilicus. Form lenticular.

Sub-genus *Helicotoma*, Salter. Depressed, discoid; spire nearly flat; whorls obtusely angular externally, rounded below; umbilicus broad. Form cirrhoid or helicoid.

Sub-genus *Ophileta*, Vanuxem. Discoidal; spire sunk above; umbilicus below perfectly open, and exposing the whorls all on one plane; whorls numerous, truncate and biangular exteriorly; mouth trigonal. Forms with deeply concave spires.

On mature consideration I cannot find any reason for separating the above series of forms, except as sub-genera. They pass into each other by almost insensible degrees, some species of *Raphistoma*, for instance, being merely depressed *Scalites*, while others need but a little more angularity below to become species of *Ophileta*. *Helicotoma* is a new sub-generic form, which I have been obliged to institute in order to express a middle term of the series, one in which the true discoid form of *Raphistoma* is maintained, without the extreme angularity of that genus, yet with a spire almost as much sunk and an

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* A fossil of the Chazy and Birdseye limestones of New York. The Maclurea may thus be regarded as representing in this rich locality the Chazy limestone, which is still further illustrated by such species as *Bellerophon sulcatinus* and *B. rotundatus*. See Preface.

umbilicus as greatly exposed as in *Ophileta*. All are Lower Silurian forms, and from near the base of the system, and all, with the exception of *Scalites* proper, which does not occur in the Ottawa limestone, are illustrated in plates 2 and 3.

The genus must be regarded, in the present state of our knowledge, as allied to *Pleurotomaria* and *Murchisonia* (which, with *Scissurella*, is now considered* to belong to the Trochidæ), but differing from them importantly in the want of the spiral band. It is probably nearer to *Ianthina*, some of the typical species of which are strongly striate in the direction of the lines of growth, and deeply notched in the middle of the mouth. These thin floating shells certainly seem to offer the best affinity with *Scalites* and its various sub-genera; and inasmuch as *Ianthina* is arranged as a family close to the Trochidæ and Haliotidæ, the association of *Scalites* with the former would not call in question its relationship to the latter. Both *Ianthina* and *Scalites* have but few whorls and a short spire (in the fossils with a much greater tendency to a depressed shape); while the Trochidæ and Murchisonia are on the contrary elongate and many-whorled.

The total absence of opercula, while it rather strengthens this view of the affinities of *Scalites*, throws some doubt on the propriety of keeping Murchisonia among the Trochidæ. Professor E. Forbes would have arranged all these thin-notched shells, with *Platyschisma* (McCoy), and some other palæozoic genera, alongside of *Ianthina*.

Raphistoma.

I have altered but little the essential parts of Prof. Hall's description of the genus. The main characters by which the sub-genus is distinguished are pointed out by him, viz.: the close-fitting sutures between the whorls, and the subtrigonal, not rounded, form of the mouth, caused by the production of the outer angle.

There are two sections even of this sub-genus, one with flat spire and the whorls convex below (*R. striata*, Hall), the other with spire and base about equally convex, and a general lenticular form (*R. staminea*, Hall, *R. lenticularis*, Sowerby, &c.). The two species here described belong to the second sub-division.

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* By Mr. Woodward, the author of the "Rudimentary Treatise on Recent and Fossil Shells." John Weale, London, 1854. This excellent work contains in a condensed form the fruits of much research, and is highly prized by European naturalists.

R. LAPICIDA, N. sp.

Plate II. Figures 1–3.

R. uncialis, discoidea, lenticularis, margine acutissimo: anfractibus 4 lævigatis, supra planis, atque suturis inconspicuis, subtus convexis; umbilico angusto rotundato; ore ovato acutissimo. Diameter, 10 lines; alt., 5½ lines.

This elegant shell a good deal resembles the *R. staminea* of Hall's work (Pal. New York, vol. i., pl. 6, fig. 4, 5), from which it is readily distinguished by the less raised spire, flatter base, and larger umbilicus. It is altogether a flatter and smoother shell, the lines of growth not sharp and regular, and on the upper surface there is no concentric ridge to interrupt the backward course of the striæ. And comparing it with other American species, the *R. (Maclurea) labiata*, Emmons, and the very similar *R. (Pleurotomaria) lenticularis* of the same author (not of Sowerby), have both more convex bases, the outer face of the whorl below being almost vertical in the former, and at least convex in the latter, instead of first concave and then prominent. The umbilicus in both is too large for ours.

The whorls of the spire slope regularly to the apex without interruption at the sutures, the last whorl excepted, which descends a little beneath the margin of the preceding. The edge is very acute. The under-side, only a little more prominent than the spire, is first concave beneath the keel, then convex towards the deep narrow umbilicus with its incurved sides. The striæ of growth are more conspicuous below than above. The rounded sides of the umbilicus easily distinguish *R. lapicida* from the next described species. The inner lip is prominent and a little reflexed. The angle of the ovate mouth very acute, and the notch deep, but the lower margin does not project greatly forward.

A general resemblance to *Helix lapicida* suggests the name.

Locality.—Allumette Island.

R. APERTA, N. sp.

Plate II. Figure 4.

R. semiuncialis, anfractibus 4 insuper depressis, subtus perangulatis: umbilico latissimo infundibulato; ore rhomboideo. Diameter, 6 lines; alt., 3 lines.

The whorls are of about the same proportionate width as in the

last species, four of them in the diameter of half an inch; they are not quite flat above, but gently convex between the sutures. Below they are strongly angular at about the middle of the volution, the outer face being plane, and the umbilicus broad and conical, with slightly curved sides; its width is fully half the entire diameter of the shell.

The mouth is rhomboidal, as high as wide, the outer angle about 80°, its lower and inner margin defined by the angle and sloping wall of the umbilicus; the margin not reflexed.

This has a more convex base than the *R. (Pleurotomaria) subtilistriata* (Hall*), which nevertheless appears to be of the same genus. *P. lenticularis*, Emmons,† also resembles ours, but it is a larger shell, and less angular below.

R. aperta is however so like *R. (Euomphalus) qualteriata* of Schlotheim from the Lower Silurian limestones of St. Petersburg, that but for the greater size and less elevated spire, it might be taken for the young of it. *R. qualteriata* however seems constantly to be more depressed above, and the outer angle therefore of the mouth not so equal-sided as ours; nor is the umbilicus quite so broad or so decidedly angulated.

There are several other species of Raphistoma in the Canadian limestone, one an inch and a half in diameter, slightly concave at the sutures, and with large angular umbilicus.

Locality.—Allumette Island.

Helicotoma.

The characters are given above, and only four species are yet known—one the *H. (Euomphalus) uniangulata* of Hall, from the Calciferous sandrock of New York, and the three species here given. *H. planulata* should stand for the type of the sub-genus, which is less regularly depressed than *Raphistoma*, and without the reversed umbilicus of *Ophileta*, though with a much larger one than the other sub-genera.

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* Palæontology of New York, vol. i., plate 37, figure 5.

† Geology Second District, New York, page 393 (not of Sowerby).

H. planulata, N. sp.

Plate II. Figure 5–7, and Variety, figure 8.

H. unciam lata, anfractibus 4 gradatis, concentricè sulcatis, supra planis; carinâ ad angulum externum elevatâ; basi tumido latè umbilicato.

Synonym.—[*Euomphalus uniangulatus*, Hall, Palæontology of New York, vol. i., plate 3, figure 1 ?] *Scalites uniangulatus*, Salter, in British Association Reports for 1851, Trans. Sect., p. 63.

Prof. Hall's specimens of the very nearly allied *Euomphalus uniangulatus* are so depressed, that " the spire scarcely rises so high as the angular ridge on the upper and outer edge of the last whorl." Ours are generally more elevated. His specimen too shews the umbilicus entirely open, and the shell therefore truly discoidal, while in ours at least half the whorl on the lower side is covered by the preceding one. They are probably therefore distinct species.

The general form is depressed, the whorls being nearly flat above, and rising a little above each other in a step-like manner, each whorl nearly twice the breadth of the preceding. They are bluntly carinate on their outer upper angle, and the carina is elevated (but is not a true band), the distinct lines of growth being curved backwards to it, and beneath it bent abruptly forwards. The whorl is concave for a short space beneath the keel, and then tumid over the sides and base. Concentric furrows occur on the margin to the number of four or five, and are often duplicate, three of the intervening ridges being more conspicuous than the rest.

The base is smooth, except the prominent lines of growth; the umbilicus steep, nearly half of each whorl exposed in it, and its edge is not angular, except in the young whorls.

The mouth is rounded, about as high as wide, and has the upper margin retreating towards the deep notch, and the lower edge brought forward. No reflection of the inner lip takes place in this species, and the general aspect is that of *Euomphalus*.

Variety *Muricata*. Figure 8.

Instead of the plain ridges round the outer border of the whorl, there are three spinose or tuberculate ridges (like those of *H. spinosa*, figs. 9, 10), but the tubercles are not strictly regular in position on the ridges, though they occur all round the shell. They may be extraneous, and so may those of the following species.

The upper surface of this variety is concave, not flat.

Locality.—Allumette Island, in siliciferous limestone.

H. SPINOSA, N. sp.

Plate II. Figures 9, 10.

H. vix semiuncialis, anfractibus 4–5, *paullo elevatis, extus carinatis, supra planis seu sub-concavis tuberculisque cristatis sparsis, subtus convexis; umbilico angusto verticali; ore sub-rotundo.*

Whether the spinose ornament be considered structural or extraneous, this is certainly very distinct from all the varieties of the last species, and more elegant in outline. The shape of the deep umbilicus, with its vertical sides, is a good deal like that of *H. larvata* next described, but the form of the shell is much more depressed.

The upper surface is rather thickly studded over with tubercles, which are disposed in sub-concentric rows, one row of large compressed crest-like tubercles along the outer carina, an imperfect row within this on the upper concave surface, and several incomplete rows of smaller size on the outer convex edge. All have an irregular appearance, and it is more than probable are only the relics of a papillate sponge, converted into silex, and having its projecting portions determined in position by the ridges of the shell.

H. LARVATA, N. sp.

Plate II. Figure 11–14.

H. semiuncialis, lævigata, spirâ lenté elevatâ; anfractibus 5, *suprâ sub-concavis, subtus convexissimis; umbilico verticali angusto: ore rotundato margineque acuto valde sinuato.*

This shell is covered so frequently with a coat of the sponge, *Stromatocerium rugosum*, as to suggest the specific name. The upper side or spire only is covered, just as the *Halichondria panicea* invests the *Buccinum* and other common univalves of the British coasts. (See Johnston's "British Zoophytes," 1st edition.)

Some specimens however, which are free from the parasite, shew the spire to be composed of five gradually increasing whorls, each about one and a-half times the width of the preceding. The whorls are slightly concave on the upper side, which is divided by an angular ridge from the convex outer border. The base is regularly

convex, the umbilicus deep and rather narrow, bounded by a sharp edge which cuts the lower angle of the mouth about its middle.

The mouth itself is rounded, very deeply notched at the upper angle, and the edge then curves strongly forward and forms a projecting outer lip. The inner margin again retreats very considerably, and has a sharp, almost cutting edge. The lines of growth in the umbilicus follow the curve of the edge of the inner lip, which is somewhat excavated, as in species of *Natica, Littorina littorea*, etc., by the reflection of the mantle's edge.

The entire form is very compact, and the smooth lower surface being convex, with small, deep, regular umbilicus, the shell has a good deal the aspect of a land-snail, a resemblance at once contradicted by the angular umbilicus, the sharp retreating inner lip, and the notched and projecting outer one.

The last two species violate in some respects the character of the sub-genus, having the small umbilicus of *Raphistoma*, with an angular edge. In truth they might be included with the former sub-genus, and are retained here on account of the rounded, not triangular mouth. *Raphistoma* is better typified by such species as have a flat or regularly conical spire, a triangular mouth, and a small umbilicus. It is always difficult to define the limits of sub-genera, for they are mostly convenient, rather than absolute, groups.

Ophileta, Vanuxem.

The characters given by the author of the genus merely describe its general appearance, and do not indicate its relations to *Raphistoma* or the other allied sub-genera. It appears to be strictly confined to the lowermost of the calcareous strata which lie upon the Potsdam sandstone, and holds the same place in Scotland as it does on the American continent.

O. compacta, Salter.

Plate III.

O. magna, sesquiuncialis, anfractibus 5–6, *utrâque perangulatis, supra profunde excavatis, infra planissimis; ore trapezoidali fere trigono, faciei internâ angustissima externa biangulata,—verticali.*

So few species are known of this genus, that it is not necessary to be minute in the specific character. This is by far the largest known.

Prof. Emmons' *O. complanata*, as figured by Hall (Palæontology of New York, vol. i., p. 11), is nearest in size, but is still greatly smaller, and has even more whorls in a shell of half the diameter. *O. levata* is a minute species.

At first sight this shell, like the *Maclurea* (plate 1), appears to be reversed or left-handed, the flatter side apparently being the spire, as in many Euomphali, and the concave one the wide umbilicus (*Euomphalus calyx*, of the mountain limestone, in form greatly resembles fig. 3). But when comparison is made with such forms as that last described—*Helicotoma* (*H. uniangulata*, for instance)—the real affinity is manifest; although the evolution of the whorls is extreme in the present case, the direction of the lines of growth is decidedly similar in the two genera.

Diameter, about one inch and a half, and height of outer whorl about six lines.

General form thick-discoidal, the upper side shewing five or six whorls, rather slowly increasing in size, steeply concave from the outer margin, so as to form a hemispheric cup. The whorls have each a sharp keel outside, which rises prominently above the general concave surface (in the cast making deep impressed furrows, fig. 1), and the lines of growth are turned considerably backward, from the suture to the prominent upper keel, *a*. On the outer vertical face they make a bold curve forwards, retreating again, fig. 4, to the lower angle, *b*.

The umbilical face, fig. 2, makes nearly a right angle with the vertical outer margin. We are unacquainted with the course of the lines of growth over this. The mouth, fig. 1 *ab*, is trapezoidal, the inner side, *c*, vertical like the outer, and parallel to it, but not above half the length. Fig. 1 being reversed, the lower or square angle of the mouth is indicated at *c*. The upper side, fig. 3 *ad*, takes of course the same slope as the spire generally, and forms with the outer face an angle of less than 45°.

The species has been quoted by me from the Lower Silurian rocks of N. W. Sutherlandshire, where it occurs in a thick cherty limestone overlying quartz rock.* A fresh comparison shews only very trifling differences. The English fossil is not quite so large, and has rathet more whorls in a given space ; but these proportions vary, and the form is exact. The *O. (Maclurea) sordida* appears to accompany it in Sutherlandshire as it does in Canada and New York.

* See Sir R. I. Murchison's Memoir on the Rocks of the N. W. of Scotland. Quarterly Geological Journal, vol. 14, ined.

Locality.—Found in a hard, brownish, calcareous sandstone (Calciferous Sandrock) at Beauharnois, near Montreal, associated with the *Ophileta (Maclurea) sordida* of Hall. The latter species has much fewer and more rounded whorls, but it is probably of the same sub-genus, as there are intermediate forms connecting this sub-genus with *Raphistoma.*

MURCHISONIA, D'Archiac and DeVerneuil.

Generic characters.—*Murchisonia*, DeVerneuil and D'Archiac. Mollusca Gasteropoda. Family, Trochidæ (see Woodward, 1858). Shell elongated, many-whorled; whorls variously sculptured, and zoned like *Pleurotomaria* by a spiral band; outer lip deeply notched; aperture slightly channeled in front.

Section 1.—*Murchisonia*, proper. Turbinate shells, with angulated and variously ornamented whorls, the band generally most prominent; mouth ovate, produced below.

Section 2.—*Hormotoma.* Elongate, beaded, with round whorls having a distinct band and notch, as in the other *Murchisonia;* mouth rounded, not effuse.

The shells which the above distinguished authors separated under this name, were long classed with *Pleurotomaria*, with which they are closely allied. They bear the same relation to the *Pleurotomariæ* of the Palæozoic rocks that *Pleurotoma* does to *Conus;* indeed there seems to be an almost perfect gradation between them. If the spire of a *Pleurotomaria* be lengthened, it becomes a *Murchisonia;* and, in like manner, if the produced mouth and spire of *Murchisonia* be shortened, the Trochoid forms so common in the Carboniferous limestone are again produced.

Probably both these genera are allied to *Scissurella*, which is not a pearly shell, rather than to the true *Pleurotomariæ* of the Oolitic rocks, which are nacreous, and clearly allied to *Trochus.* But we have not the means, in the absence of the operculum, to establish this point.

Prof. E. Forbes thought the whole group of these thin palæozoic shells with notched apertures were related to the Ianthinidæ. And it is probable this is a correct view, though these could scarcely be pelagic forms, associated as they are with numerous other types of molluscs, annelides, crustacea, etc., and *frequently* found gregarious

in sandstones and conglomerates which must have been formed in a shallow sea. They appear to have inhabited however every kind of sea-bed (though more abundant in those of a sandy character), and are common throughout the limestones of the New York and Canadian series.

It is probable that the angular-whorled and strongly-striated species belong to a different genus from the elongate, beaded forms. But they are at present kept together under one name, as sub-genera.

M. BICINCTA, Hall.

Plate IV. Figures 5, 6 (and 7 junior).

Specific characters.—M. pyramidata, biuncialis, anfractibus 6–7, *acutiangulatis (valde distinctis), lævigata—carinâ primariâ crassâ trilineatâ suprâ medium anfractûs—secondriâ obtusâ ad suturam positis; umbilico parvo; ore ovato effuso.*

Synonym.—M. bicincta, Hall, Palæontology of New York, vol. i., plate 38, fig. 5. [*M. perangulata*, ib., plate 10, fig. 4. junior.]

The shape of this common and fine species is rather abruptly but regularly pyramidal, the spire composed of six or seven whorls, each sharply angulated in the middle, or rather beneath the middle in the whorls of the spire, but considerably above it on the body-whorl. The keel is thick and prominent, ornamented with three faint-raised threads, one along the middle.

Beneath the principal carina a second, much less prominent and obtuse, abuts against the suture (in the spire), and occupies a position rather below the middle of the body-whorl. The slope of the whorl above the principal keel is nearly straight, not concave; between the principal keel and the lower one a little concave, and beneath the last the whorl is convex as far as the small umbilicus. The mouth is ovate, gently effuse at base, and the columellar lip straight and reflected, but apparently not closing the umbilicus.

The surface, unlike that of most of the accompanying species, is smooth; the lines of growth obscure, but a good deal bent back. The triple keel is not serrated or even decussated by them, but quite even-edged.

M. perangulata, Hall, has a more elongate spire, but does not appear to differ specifically from young specimens of *M. bicincta*. Those from Canada are more like what Prof. Hall has figured from

the Birdseye limestone; that in the Trenton limestone (pl. 38, fig. 7) seems a more elongate species. Our specimens may however be distinct, as the author does not mention the small carina round the sutural edge of the whorl, conspicuous in *M. bicincta* when young, but much fainter when full-grown. The base too is less convex and the umbilicus more distinct. But these are minute differences, and from examination of a series, I am much disposed to unite the two species.

Locality.—Allumette Island. There is another species associated with these, and differing chiefly by having strong upper and lower keels; and there are several new *Pleurotomariæ*, distinguished by their shortened form from the present genus.

M. SERRATA, N. sp.

Fig. 1.

M. latè conica, spirâ brevi; anfractibus 4 acuticarinatis, carinis 4 serratis, spatiis intermediis concavis et striis conspicuis; basi convexo, ore rotundato.

The spire is less produced than in the preceding, forming an angle of fully 55° or 60°, and composed of four acutely carinate whorls, deeply separated at the sutures. The body-whorl is furnished with four keels—the principal one *very prominent* about the middle of the body-whorl; one keel above it, near the suture; another at an equal distance below; on the convex base there is a fourth, which surrounds at some distance a rather large umbilicus, the sides of which are very convex. The keels are all more or less serrate, the principal one especially so (and not so much undulated as our figure shews); and the spaces between them are deeply concave—that between the upper keel and the suture nearly horizontal, but still hollowed out. The lines of growth are sharp and equidistant, decussating the keels to produce the serrate edges, and bending back considerably to the central prominent one, which is so narrow as not to shew a distinct band.

This beautiful species is more sharply keeled than any other Silurian species known to me, and reminds one of some of the Carboniferous forms.

Locality.—Allumette Islands.

M. HELICTERES, N. sp.

Plate IV. Fig. 2–4.

M. turrita, biuncialis, anfractibus 5 sub-rotundatis, tricarinatis antiquatis, ultimo vago: carinis omnibus obtusis, medianâ (cingulo) latâ; striis crebris asperis.

This shewy species is not more remarkable for the irregular uncoiling of the last whorl (resembling in this respect certain varieties of the common snail, *Helix aspersa**), than for the rough striation and antiquated appearance of the whorls.

The band or principal keel is broad and flat, the upper and lower edges being prominent, and the middle only a little convex; the rounded notch is rather deep. The upper and lower keels are obtuse, and equally distant from the band, the upper placed about half-way towards the suture, which is not at all channeled; its edge on the free whorl shews as an obtuse ridge. See figure 3 *s*.

The spire is pyramidal, but the separate whorls are rounded; the upper ones have the inferior carina covered by the suture, but it is exposed in the lower one by the divergence of the last whorlt figure 2, which afterwards becomes quite free, figures 3, 4.

The striation is very rough and coarse; the lines of growth crossing the ridges, give these an antiquated appearance. The mouth is round; the shell thickened, especially on its inner side.

In the thick, obtuse whorls, coarse striation, and broad band, this species a good deal resembles *M. semirotundata*, McCoy, from the Caradoc formation of N. Ireland, but that species is destitute of the upper keel, besides having much rounder and more ventricose whorls.

M. tricarinata, Hall, (Pal. New York, vol. i., plate 38, fig. 6,) is a Trenton species much more resembling our shell; but his specimens are too imperfect to identify with, particularly as he mentions nothing of the tendency to uncoil, and distinctly says there is no umbilicus; the carinæ, too, are represented as sharper than those of our species. Moreover, the mouth is said to be "acutely" produced below. It has, however, similar sharp prominent striæ, and is probably very nearly allied.

Locality.—Common at Allumette Islands.

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* See Gray's edition of "Turton's Manual of British Shells." (Vignette.)

Section HORMOTOMA.

Elongate, beaded forms, like *Holopella*, but with a distinct band and notch, as in the other *Murchisoniæ*. Mouth rounded, not effuse.

M. GRACILIS, Hall.

Plate V. Figure 1.

M. *elongata, biuncialis, anfractibus* 10–13, *ventricosis, rotundatis (supra vix planulatis), cingulo centrali lato, etiam quartam partem anfractûs æquante.*

Synonym.—Hall, Palæontology of New York, volume i., plate 39 figure 4; page 181.

This gracefully-formed species belongs to a group of *Murchisoniæ*, which doubtless ought to be separated generically from the more typical angulated forms. They resemble *Holopella*, McCoy (the so-called *Turritellæ* of the Silurian rocks), in the elongate, beaded form, and round, instead of oblong and effuse, aperture. The band however effectually distinguishes them. The inner lip, too, is reflected on the columella, which is probably not the case with *Holopella*.

M. gracilis is a fine species, full two inches long, and very gradually tapering; of about twelve or thirteen round whorls, which are only very slightly flattened on the upper side, above the band. The latter is broad, equal to about one-fourth the whole width of the whorl, and placed centrally or a very little below the centre. ("On the centre," Hall.) The striæ, which are close but not prominent, curve sharply backward to this band, and forward again beneath it.

The slight angularity of the whorls is alluded to by Prof. Hall, who compares it in this respect with the larger species, *M. bellicincta*, of the same limestone. This slight angle does not however detract from the general roundness of the volutions, as represented in the figures above referred to. It is an exceedingly plentiful species.

Our figured specimen has the outer portion of the last whorl broken away so much that the inner lip *(a)* looks far more conspicuous than it is in reality. It is slightly reflected over the columella.

Locality.—Abundant in the slabs of limestone at Pauquette's rapids, etc.

M. VENTRICOSA, Hall.

Plate V. Figures 2, 3.

M. turrita, anfractibus rotundatis ventricosis lævigatis, supernè subangulatis, et cingulo lato marginato prope suturam posito; ore rotundato.

Synonym.—M. ventricosa, Hall, Palæontology of New York, vol. i., plate 10, figure 3.

The position of the band easily distinguishes this fine species from the *M. bellicincta*, Hall, with which its size and general shape would lead us at first sight to identify it. It has the same proportions of spire, and convexity of the whorls, and the pillar-lip is straight, as described by Hall, though his figures do not clearly shew this character.* But the band, instead of being nearly central and rather narrow, is broad, flat, and placed so high up as to be less than its own breadth from the suture; while the lower margin forms the prominent angle seen above the middle of the whorl. The lines of growth curve back much in the way figured in the *M. bellicincta*, and far less sharply than in *M. gracilis*, tending back to the broad band, in which they are much curved, and then forward again, leaving an open angle of about 100°.

Any comparison with other allied species seems unnecessary, as, except *M. bellicincta*, there is no American species likely to be confounded with it. *Pleurotomaria inflata*, McCoy, Silurian fossils, Ireland, is a kindred species, but quite distinct.

It is found in tolerable plenty associated in the same slabs with the *M. bicincta*, *Orthoceras arcuoliratum*, *Cyrtoceras Billingsii*, and *Strophomena planumbona*, at Allumette Islands. Hall's specimens were found at the junction of the Birdseye and Trenton limestones in the Mohawk valley.

CYCLONEMA, TROCHONEMA, EUNEMA.

Decade I. Plate VI.

CYCLONEMA, Hall.

Cyclonema, Hall. Mollusca Gasteropoda. Family Litorinidæ.

Turbinate, thin, of few ventricose whorls, with concentric striæ

* It is with some doubt this is referred to Hall's very imperfect figured specimen. His description however agrees accurately, and it is useless to multiply names.

or ridges, crossed by oblique, straight (or very slightly sinuous) lines of growth. No umbilicus. The mouth rounded, and with an imperfect peritreme. Inner lip thin, closely reflected, and a little concave.

Trochonema, Salter.

Trochonema.—Mollusca Gasteropoda. Family Litorinidæ. Turbinate, thin, of few angular whorls, marked by strong concentric ridges, and crossed by very oblique lines of growth. Umbilicus wide, open. Inner lip thin, scarcely reflected; peritreme complete.

Eunema, Salter.

Eunema.—Mollusca Gasteropoda. Family Litorinidæ. Turbinate thin, of few angular whorls, marked by strong concentric ridges, and crossed by strongly sinuate, prominent, and thread-like lines of growth. Inner lip not reflected; peritreme simple; mouth rather effuse below; no umbilicus.

Loxonema, Phillips.

Loxonema.—Mollusca Gasteropoda. Family Pyramidellidæ. Elongated, many-whorled; aperture simple, attenuated above, effuse below; lines of growth (marking the form of the outer lip) sigmoidal; no umbilicus.

The characters of these four genera which have been figured together are here given in order to shew in what points they differ, and what analogy and gradation of form subsists between them.

Taking *Trochonema* as the most depressed and widely umbilicate form, or with simple and very oblique lines of growth, the next step would appear to be *Cyclonema* or *Holopea*, in which the umbilicus is closed, and the lines of growth a little sigmoid, or at least sinuate, below. *Eunema* is still more elongate, and the lines of growth decidedly sigmoid; while it is difficult to say if *E. pagoda* more properly belongs to this genus or to *Loxonema*, in which the edge of the outer lip, indicated by the lines of growth, is sigmoid, and the entire form elongated.

Yet notwithstanding this apparent passage established by such forms as *Eunema*, it is probable that *Loxonema* belongs to an entirely different family (the *Pyramidellidæ)*, and that the rest are thin-shelled forms of *Litorinidæ*, with an evident tendency towards the fragile *Ianthina*, with which the rudimentary sinus in the outer lip also helps to connect them.

Professor Forbes thought *Holopea* (and therefore *Cyclonema*, which is closely allied,) much like *Litiopa*, a pelagic form of the *Litorinidæ*, and they both have the concave inner lip of *Litorina*. There is some difficulty in determining the nearest recent analogue of *Trochonema*. It may be compared with *Skenea (Litorinidæ)* or with *Adeorbis* (i. e., *Cyclostrema)*, which differs from the other Trochidæ in its non-nacreous shell. *Eunema*, it is true, has the sinus of the outer lip so much increased as to separate it from any recent forms of *Litorinidæ*, while it much resembles *Ianthina* or the allied genera *Recluzia*, which has an an extremely simple, paludiniform shell. It has a much thicker shell, however, than these, and its affinities are with the fossil genera above described, from which the elongate form and sinuous outer lip effectually distinguish it.

The fossil shells under consideration appear to be all too solid for comparison with floating shells, and the tendency they exhibit to form projecting and irregular apertures in old age indicates rather a *ground-feeding* and ultimately *sedentary* habit.

CYCLONEMA.

With regard to the limits between *Holopea* and *Cyclonema*, not much that is satisfactory can be said. The form is similar, and the striæ or ribs are not always present in the one or absent in the other. The possession of a concave reflected inner lip, if it could be established for *Cyclonema*, would be a good character, yet certain species in the Canadian collection which are quite smooth, and have the general character of *Holopea*, resemble *Cyclonema* in this, though they want the characteristic sculpture. *Holopea* seems to be sometimes *(H. obliqua*, Hall,) umbilicate, and sometimes not so. *Cyclonema* is never umbilicate, and the inner lip is concave in the type species.

If accepted as a genus, *Cyclonema* should include all those Silurian species hitherto referred to *Turbo*, *Euomphalus*, etc., which have concentric ridges and oblique lines of growth. Although this is only a superficial character, it is found in so many species, that, combined with the thin shell, it may be taken into account.

Euomphalus granulatus and *E. lineatus*, Portlock, *Turbo crebristria*, McCoy*, and *T. sulcifer* of Eichwald, in addition to those described by Hall, will certainly fall into it. These, with numerous concentric ribs, none of which are specially prominent, lead the way easily to such forms as *T. rupestris*, Eichwald, in which most of the ridges are suppressed, and a few large ones only remain. The bands of color follow the direction of the ridges in the last named elegant species.

T. trimarginatus, Eichwald, is another similar form. It is difficult, if not impossible, to draw the line between such species as these and the several gradations which lead back to *C. bilix* or the fossil here figured. The group appears to range into the Devonian rocks, as we learn from the figures of the MM. Sandberger of Nassau.

C. Halliana, N. sp.

Plate VI. Figure 1.

C. turbinata, ventricosa, anfractibus 5 rotundatis, supra paullulum planatis,—ultimo ad basin gibboso, striis que concentricis undulatis cincto; basi subangulatû lævi; ore rotundo.

It is not difficult to distinguish this from the *C bilix* (*Pleurotomaria bilix*, Conrad), for the whorls are much rounder and the spire consequently not nearly so conical; the striæ only cover a part of the whorl, and the pillar-lip is not so straight or so much reflected. The species are however very closely allied.

The whorls are rounded, and even rather gibbous toward the lower part, but there is a decided flattening above, and the base too is a little flattened (not nearly so much as in *C. bilix*). The lines of growth are oblique backwards, as far as the basal angle, if it may be so termed, and thence turn forward, making a slight sinus. [This character is even more decided in the *C. bilix*, and is greatly exaggerated in the genus *Eunema*.]

The suture is well pronounced, the upper part of the whorl free from concentric striæ, which occur only on the sides; the base also is smooth. The mouth is roundish, a little prominent only beneath the columellar lip, which is not quite vertical, nor is the inner lip much reflected or more than slightly concave.

Locality.—Pauquette's Rapids.

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* Palæozoic Fossils, Woodwardian Museum, Cambridge, Plate 1 L, figure 22.

C. SEMICARINATA, N. sp.

Figure 2.

C. semiuncialis, spirâ regulariter conicâ, nisi suturis horizontalibus insectâ; striis obscuris; anfractibus 4–5 supra biangulatis, infra 6–carinatis, carinâ secundâ maximâ medianâ, quartâ prominulâ; ore rotundo.

Of this well-marked form there are only two or three specimens, the largest not above half an inch in height. They were first taken for *Pleurotomaria percarinata*, Hall, which, as it shews nothing of the characteristic band or notch, may very probably belong to *Cyclonema*. But in that species the sutural space is not horizontal, and the conical spire seems therefore blunt instead of deeply incised, while the keels below the chief ridge are mostly equal.

There are two or three other species in the Ottawa limestone, one beautifully ornamented, and like a *Pleurotomaria* in everything except the notch.

Locality.—Allumette Islands. *Holopea obliqua*, Hall, accompanies it.

TROCHONEMA.

Under this proposed name will fall several Upper and Lower Silurian species, such as the *Turbo trochleatus* of McCoy, and *Euomphalus tricinctus* of the same author; only those however with the strong concentric ridges possess a wide umbilicus. *Inachus angulatus*, Hisinger, is probably an extreme form of the group, with a greatly depressed spire. *Pleurotomaria umbilicata*, Hall, is the one here described, and the type of the genus.

T. UMBILICATA, Hall.

Plate VI. Figure 3.

Troch. unciam lata, depressa; anfractibus perangulatis, facie externâ latâ verticali; umbilico latissimo, tumido, carinâ obtusâ permarginato.

Prof. Hall, Palænotology of New York, vol. i., plate 10, fig. 9, and pl. 38, fig. 1; p. 43–175.

Turbinate, depressed, the last whorl often free; the spire short, truly conical, interrupted only by the vertical faces of the whorls and the hollow sutural edge. Volutions, 4 or 5, with 4 carinæ, of which two

on the middle of the whorl are strong, prominent angles, enclosing a broad, vertical, slightly concave space (the upper angle rather the more prominent); one close to the deeply canaliculated suture; the fourth only visible on the base, margining a very broad umbilicus.

The space between the upper and second carina is more concave than that below the latter, while between the third and fourth the space is a little convex, not quite flat. The umbilicus is first concave and then tumid; it exposes the second and part of the third whorl. The mouth is round-ovate—the obliquity from above outwards—and thickened at the basal angle formed by the lowest keel.

Hall's specimens are all more or less distorted and compressed; hence his description, though accurate, does not fully agree in all points. The character of the angular volutions, with the concave spaces between short depressed spire and wide umbilicus, enables us to recognize the species; and I am further assured by Mr. E. Billings that there is no doubt of their identity. But the species must be more variable than the Canadian specimens shew, since Hall figures and describes forms (plate 38, figure 1 *g*) more elevated, and others (plate 38, figure 1 *e*, and plate 10, figure 9 *b*) more depressed than any of ours. The base of none of his specimens is ventricose, and I think that must be due to oblique pressure in his specimens or to their being mostly internal casts.

The description, by Prof. McCoy, of his *Turbo trochleatus** agrees well with ours, except in the rounded base and small umbilicus; it has a less deep suture, as his figure shews, and the space between the two bands on the whorl is decidedly narrower. These differences are here noted particularly, as I had provisionally referred the Canadian shell (see Reports British Association, preface) to the *T. trochleatus*, McCoy. Now that we know the position of the Galway rocks as Middle Silurian, it is the less likely that any species should be in common with those of the lowest formations of Canada.

Pleurotomaria latifasciata, of the same author, is another species so like ours, that it seems hardly distinguishable, except by the longer spire.

Locality.—*T. umbilicata* is a common species occurring in nearly all the slabs from Pauquette's Rapids. It ranges from the Birdseye to the Trenton limestones, in New York.

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* Silurian Fossils, Ireland, plate i., figure 9.

Eunema.

The typical species may be considered *E. strigillata*, which has an elongate form, and the striæ bent forwards below the sinus; while there are others with the lines of growth vertical below, or scarcely at all brought forward. These latter connect it with the *Cyclonema*, but have still the produced mouth and more turrited form, which gives them the aspect of *Murchisonia*.

E. strigillata, N. sp.

Plate VI. Figure 4.

E. turbinata, elongata, anfractibus 6 *obliquis, sæpe vagis: carinis tribus æquidistantibus, superiori ad suturam, secunda supra medium positis; cunctis à striis asperis dichotomisque decussatis; ore ovato.*

This beautiful shell is quite abundant at Pauquette's Rapids, and many finely-weathered specimens shew the characters well. It is a thin shell, and the striations of the surface are remarkably sharp, prominent, and regular.

Shell elongate, turbinate, of about six rather oblique whorls, the last sometimes free. There are three prominent ridges on each whorl, the principal one placed much above the middle of the body-whorl, the upper one near the suture, the lower at an equal distance below the median keel. All are crossed by equal, sharp, close, thread-like ridges of growth, which tend about 60° backward to the principal keel, where they are sharply bent, and proceed a little forwards over the sides and base; the open angle of the notch so formed is about 130°. They bifurcate regularly between the upper and middle keel, and re-unite in pairs upon the base, which is produced. The mouth is oval, a little pointed above, and below somewhat effuse. There is no umbilicus, and the inner lip is not reflected or pressed closely against the columellar base, which has a slight angle upon it.

Locality.—Pauquette's Rapids.

E? PAGODA, N. sp.

Plate VII. Figure 5.

E. turrita, elongatissima, anfractibus 10–11 *depressis tricarinatis; carinâ superiori remotâ minimâ, suturam profundam approximatâ; medianâ inferiorique fere æqualibus, eminentibus: cunctis crenulatis, striis obscuris (retrorsis?).*

A much elongated, turrited shell, of about ten or eleven very convex beaded whorls, very gradually increasing in size, and furnished each with two prominent keels, besides a smaller one along the sutural edge. Of the principal keels the upper is rather the more prominent, and placed about the middle of the whorls in the spire, but above it on the body-whorl. The space above it is a regular slope, between it and the third keel concave, and below the third also concave for a somewhat greater space as far as a fourth, which only shews on the base of the body-whorl, being covered by the suture in the spire Mouth, unknown.

The keels are all more or less crenulated, evidently by the lines of growth, but these are so obscure that it is impossible to say whether they are oblique backwards, as in *Eunema*, or arched forward, as in true *Loxonema*. The species might be referred to either of the two genera, but as yet we know of no *Loxonema* with strong spiral keels, while they are characteristic of *Eunema;* it is therefore safest to leave it in the present genus, especially as there are other smaller species not described here, of quite as elongate a form, in which the course of the lines of growth is not doubtful.

Locality.—Frequent on slabs of limestone, in company with many of the foregoing species, at Pauquette's Rapids. Another new species resembles a small *Cerithium*, and might be termed *E. cerithioides.*

LOXONEMA, Phillips.

The species of this genus are but rare in Lower Silurian rocks. One is introduced here to compare with the most extreme forms of *Eunema*. The inner lip is still more incomplete, and the curve of the striæ more sigmoidal.

L. Murrayana, N. sp.

Plate VI. Figure 6.

L. $2\frac{1}{2}$ *uncias longa, anfractibus regulariter convexis etiam inflatis, ne supra planulatis, (ad suturam vallo angusto notatis,) striis concentricis obscuris, striis incrementi conspicuis, antrorsum arcuatis: umbilico nullo; ore obovato.*

The length of this species must have been full two and a half inches, and the diameter of the lower whorl not less than three quarters of an inch. The whorls are very convex. almost inflated, and have no special prominence in any part; their base is a little produced. The sutural edge is a fine raised thread, and beneath it occurs a narrow flattened space (with a raised border on the lowest whorl). There are a few faint concentric striæ, but the lines of growth are the only prominent ones; they are strong, sigmoid, the backward curve short, the lower forward one a broad arch, reaching further forward than their origin at the suture. There is only a minute umbilical depression, with no bounding ridge, and the inner lip is incomplete, its edge simple, not reflected.

A single specimen only has occurred of this fine shell, and I have pleasure in naming it after Mr. Alexander Murray, who has labored so long in the Canadian Survey.

Locality.—Pauquette's Rapids. *Murchisonia* (Loxonema ?) *subfusiormis*, Hall, appears also to occur in this limestone.

Cyrtoceras, Goldfuss.

Generic characters.—*Cyrtoceras*, Goldfuss. Shell curved or partially involute, sometimes with the transverse, at others the longitudinal, diameter the greater. Aperture often contracted (in the smooth forms). Siphuncle subinternal, central, or external. (Barrande.)

Section *Cyrtoceras.*—Curved; siphuncle variable in position, simple,

——— *Gyroceras.*—Involute; siphon internal or subcentral, solid, radiated.

It is not easy, in the absence of a perfect structure in the siphuncle, to separate *Cyrtoceras* from *Gyroceras*, the principal difference being the more regularly involute form and ornamented surface in the latter (just as in the case of *Toxoceras* and *Crioceras* among the genera with foliated septa).

Indeed it is much to be wished that a name so ill applied as *Gyroceras* should be abolished altogether. Originally given by Meyer to the *Spirula compressa* of Von Buch, which has since proved to be a *Goniatites*, M. d'Orbigny had no warrant for applying the name to a totally different form. And as the *position* of the siphon will not distinguish the two genera, there remains but the somewhat obscure character of its more solid *radiated structure* to separate the two genera. It would be better to reunite them, and when the value of this character is better known, to complete the classification.

We are fortunately able to present two extreme forms of the genus in one plate: the one smooth on the surface and much laterally compressed, as in the several Silurian forms; the other ornamented with large, frill-like varices of growth, and with a wide section, like those of the Devonian species. Some of these latter (referred to *Cyrtoceras* by Goldfuss and Phillips,) are as much involute as a *Lituites*, and are wide in section, the fore and aft diameter, so to speak, being less than the tranverse measure.

CYRTOCERAS FALX.

Decade I. Plate VII. Figure 1–4.

Synonym.—*C. falx*, Billings. Report of Progress, Geological Survey of Canada, 1857, p. 314.

A smooth shell, or with very faint and nearly direct lines of growth. It is strongly curved, and somewhat compressed, about two inches long, rapidly tapering from ten lines broad to two and a half, and in some specimens more quickly. Aperture oval, ten lines broad by eight thick. Siphon nearly close to the peripheral margin. Septa close, concave from back to front.

I have Mr. Billings' own authority for identifying this shell with the species described by him, else I should have regarded it as rather belonging to the other allied species (from the same locality) which he has termed *C. simplex*. As the specimen figured—and others still more perfect—are in the Canadian Museum—I beg to refer to his description in the Report of Progress of the Geological Survey, published 1857, pp. 313, 314,) for the specific characters. It might be compared with *C. macrostomum*, *C. arcuatum*, and *C. camurum*, Hall, but all have more distant septa.

Locality.—Pauquette's Rapids.

C. Billingsii.

Plate VII. Figures 5, 6.

C. 2–3 unciale, in juventute subcylindricum involutum, in œtate depresso-ovale, rectius; annulis remotioribus elevatis undulatis in dorso sinuatis; septis approximatis planis, siphunculo externo; suum diametrum a margine remoto.

Synonym.—C. lamellosum, Hall, Palæontology of New York, vol. i., plate 41, figure 2 (not of DeVerneuil and D'Archiac).

Prof. Hall's description, taken from a young and very imperfect specimen, is clearly applicable; but this species must receive a new name, since the *C. lamellosum*, a nearly allied species from the Eifel limestone, differs both in the less rate of increase in the whorl, and the lamellæ are much closer. The curve of the tube is also more gentle. But for these proportional characters, which however are quite sufficient in this genus, it would be difficult to separate the Devonian species, which the Professor seems to have overlooked, as he describes his fossil as new. I adopt such parts of his description as are applicable to the adult form.

Subcylindrical when young, at a diameter of seven lines (and regularly involute?), but soon attaining a more open curve and becoming laterally expanded, the dorso-ventral diameter being to the lateral as nine lines to thirteen, when this diameter is attained. The tapering is more rapid in the young than in the adult portions.

The lamellæ are rather coarse and somewhat irregular in distance. (*C. lamellosum* has them very close and regular.) In figure 6 they are not more than a third of a line apart in the young portion *(a)*, and less than a line distant in the older portion *(b)*, while in figure 5 they are fully two lines apart in the same diameter, and become closer again in the adult portion *(b)*, where the distance is again not more than a line or a line and a half.* Their course is direct over the sides and inner margin, but on the outer (ventral) surface they turn rapidly backward, forming a distinct sinus. They are rudely fimbriated, with "transverse, undulating, squamose lamellæ, abruptly bent backwards on the dorsal line," and several obscure, longitudinal furrows cross them. "The spaces between the lamellæ are marked

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* Such a change in the ornament is not unfrequent in the *Cephalopoda*, and indicates probably a more vigorous growth in middle age.

by fine transverse striæ." Septa close (Hall), very flat. Siphuncle small, its own diameter distant from the outer or ventral* border.

Of this elegant species only two examples have as yet occurred, both of which are figured.

Locality.—Allumette Islands. *C. annulatum*, Hall, is more rare. *Orthoceras arcuoliratum*, *O. bilineatum*, and *O. laqueatum*, are also found, the first very common indeed; and the *Gonioceras anceps* of the Black-river limestone occurs with these. (See Preface.)

Ctenodonta, Salter.

Ctenodonta, Salter, 1851. Mollusca Lamellibranchiata. Family, Arcacidæ. Nearly equilateral, generally transverse, anterior side largest; beaks, approximate, not prominent; hinge-line with a double series of bent teeth, connected by smaller ones beneath the beak; ligament posterior, external, on a fulcrum: no striated area or cartilage pit; muscular impressions strong (with supplementary scars), not bounded by elevated ridges; pallial line simple.

I was not aware, when I proposed the above generic term for a group of palæozoic Nuculæ†, that the principal species had been previously published under the name of *Tellinomya* by Prof. Hall. His recent descriptions‡ shew this to have been the case, and if the name did not convey an entirely erroneous view of the affinities, I should have been glad to restore it. But the chief characters of the genus reside in the hinge and teeth, which are neither figured nor described by him, casts only of the interior and the external surface having been given in the plates of his excellent work, nor was the external ligament observed.

Mr. S. P. Woodward, in his most able treatise on the Mollusca, has included my proposed genus under *Isoarca* of Munster, a group of nuculoid shells which have the peculiarity of *Ctenodonta* so far as the external ligament is concerned. But in *Isoarca* there is a ligamental area, as in *Arca* and *Cucullæa*, and the tumid beaks are remote,

* The outer margin is often called dorsal, but there is an objection to using terms in direct contradiction to the anatomical structure.

† Reports British Association, 1851. Trans. Sect., p. 63.

‡ Descriptions of New Palæozoic Fossils; extracted from the Reports of the Regents of the University, Albany, 1856, p. 142.

subspiral, and in the typical species (*I. cordiformis*, Schübler, and *I. subspirata*, Munster,) quite toward one side. It may be doubtful if such species as *I. lineata* of Munster and *Nucula elliptica* of Goldfuss, which have subcentral beaks, do not belong to *Ctenodonta;* they are smooth, or with a concentric lineation only, while *Isoarca* is often cancellate.

Solenella, Sowerby, has an external ligament like *Ctenodonta*, but a notched pallial line.

The genus has been referred to in the third edition of "Siluria," p. 213, 859. It will include, as I believe, *all* the Silurian Nuculæ, and a considerable number of the other Palæozoic species. It probably extends, as above stated, into the *Trias*.

C. NASUTA.

Plate VIII. Figures 1, 2.

C. biuncialis et ultra, transverso-ovata, lævis, nisi anticè rugis concentricis; latere antico rotundato, postico subcontracto elongato, haud carinato; umbonibus depressis.

Synonym.—*Tellinomya nasuta*, Hall, Palæontology New York, vol. i., plate 34, figure 3. *Ctenodonta Logani*, Salter, in British Association Reports, 1851. Trans. Sect., page 63. *Isoarca Logani*, Woodward, Manual Shells, page 269. *Tellinomya nasuta*, Hall, Report of the Regents of the University, Albany, 1857, p. 143, fig. 1–3.

A beautiful species, not unlike in shape to some species of *Anatina* or *Thracia*, and, from the subcentral position of the beaks, very unlike the usual appearance of *Nucula*.

It is the largest known species of the genus, full two and a half inches wide, by one inch and a quarter long, measuring from the slightly prominent beaks, which are much nearer the anterior than the siphonal end. The depth of the valves, united, comprises three fourths of an inch.

The general contour is transversely ovate. The anterior side perfectly rounded and marked with concentric rugæ, which are strongest on the upper portion. The posterior side narrows considerably, and is a little contracted at the posterior third; its surface is smooth and gradually less convex towards the subtruncated end;

the posterior slope or ridge only excepted, which is convex, but not at all carinate. There is a slight groove below the straight cardinal border.

The ligament fulcrum extends to full half an inch from the beak, and the ligament itself (often perfectly preserved in the silex) is convex, and rather conspicuous. The teeth are straight, vertical, and set on a moderately broad edge; there are about eleven or twelve on each side, arranged nearly in a direct line; the hinge-plate which bears them is narrowest on the anterior side, and beneath the beak much contracted in depth. (In the next species it is considerably broader.

Locality.—Allumette Islands. A new species of *Lyrodesma* occurs with it, distinct from *L. plana* of the Trenton limestone.

C. Logani.

Plate VIII. Figure 3.

C. uncialis, convexa, anticé rotundata fere gibba, posticé subtruncata obtusi-carinata; umbone subcentrali eminente; dentibus anticis 7, *posticis* 9 *curvatis.*

Synonym.—*Tellinomya dubia*, Hall, Report Regents University, pl. *c*, figures 4, 5 (not of Pal. New York, plate 34, vol. i.).

An elegant species, which might, till closely examined, pass for a variety of the last. It is much more convex, and almost gibbous anteriorly: the posterior side more decidedly contracted and sub-carinate above. The beak is rounded, but elevated and placed centrally, or rather nearer to the subtruncate posterior end than the other. There is no lunette.

The teeth are placed on a gently curved hinge-plate, which is not indented by so prominent a ligament fulcrum as in the other species. Those on the anterior side are straight, prominent, and simple; the posterior ones are bent towards the centre, and those beneath the beak crowded, no space being left between the anterior and posterior sets.

The anterior shews that the adductor impressions were not so deep as in the next described and smaller species.

As the larger fossil above described cannot bear the name I had originally proposed, and as the name *Ctenodonta Logani* has appeared

in print, I wish to apply it to this fine species. Professor Hall has figured it under the name *dubia*, but the figures given in his Palæontology of New York, plate 34, shew that species to have been smaller and wider, the "length almost twice the height." It is much more gibbous too, according to his figures, the edge being turned quite abruptly inward. Mr. Billings, who has seen specimens of the *C. dubia*, assures me they are distinct.

Locality.—With the last. Rare.

C. CONTRACTA.

Plate VIII. Figures 4, 5.

C. parvula, tres partes unciæ lata, trigonula, subæquilatera, anticé rotundata, posticé cuneata carinata contracta, umbonibus elevatis præ medium positis; lunulâ distinctâ; cardine dentibus majoribus.

Synonym.—Tellinomya cuneata, Hall, Report, l. c., figures 6, 7.

A common but pretty little species, which well illustrates the character of the genus as distinct from *Nucula* or *Leda*, to either of which it bears a strong resemblance. Instead of two rows of teeth separated by a spoon-shaped process to carry the ligament, the two rows run into each other, with only a slight angular notch to separate them, and the ligament is clearly seen outside, set on its prominent fulcrum.

The form is that of a wide triangle, with the gently elevated beak rather nearer the anterior end. This is rounded into the ventral border, which has its greatest convexity in advance of the line of the beak. The shell too is most convex here, and a depressed line separates the elevated and carinate siphonal ridge. The posterior cardinal slope is flat in some specimens, and nearly so in all; the ligament fulcra marked out on it as a long oval lunette extending half-way along it. A similar lunette, more deeply sunken, marks the anterior side. The ligament itself is but small.

Teeth about six or seven on each side; beneath the beak a few crowded ones occur; they are straight, or nearly so, and set obliquely inwards on both sides of the broad, bent hinge-plate. The beak considerably overhangs the hinge (fig. 5*a*).

The shell is thick, the impressions of the adductor muscles deep, and close under the hinge-line. A small accessory scar occurs above

each impression. A thickened ridge lies on the inner side of each, strongest behind the straight-edged anterior impression.

Fig. 4 shews the variety with the flat or vertical posterior slope; fig. 5 has it slightly convex.

Locality.—Plentiful in the Allumette limestones.

C. GIBBERULA, N. sp.

Plate VIII. Figure 6.

C. subtrigona, rudis, 9 *lineas lata, margine antico cardinali gibbo; latere antico magno, convexo, lunulâ nullâ; postico brevi subcarinato; cardine dentibus modicis.*

Differs from the last by characters not very obvious at first sight, but these grow more evident by study, and it seems to bear the same relation to *C. contracta* that the *C. obtusa* does to *C. Logani.* The form is trapezoidal rather than triangular, and of unequal sides; the posterior bluntly pointed and small; the anterior large, gibbous and rounded; the ventral margin almost straight. The beak is considerably nearer the posterior side. It is not very prominent, the valves being most convex all along the anterior slope which overhangs the hinge-margin all along; the sinus which separates the somewhat pointed posterior side falls under the beak, and consequently near to that margin; and the posterior slope is bluntly carinate, and so short as to be not far from vertical. The ligament fulcra are marked out by a narrow lunette, which the beak overhangs.

The hinge-plate is bent at an obtuse angle, and bears about ten teeth on each side, which are set obliquely, as in the last species. The shell is thick, but the muscular impressions are scarcely visible in our specimens. A few antiquated lines of growth near the margin shew that our specimen is full-grown.

Notwithstanding the above important differences, there is much similarity to the last species in habit, the distinction being chiefly due to the exaggerated development of the anterior side.

Locality.—Not uncommon in the Allumette limestone.

C. ASTARTÆFORMIS, N. sp.

Plate VIII. Figure 7.

C. crassa, vix semipollicaris, trigona, nate curvo, excelso: margine postico lente concavo, reliquis convexis; superficie lineis crebrissimis rugisque concentricis ornatâ: dentibus pluribus, fractis.

A small, thick shell, higher than wide, triangular, with a greatly elevated and somewhat curved beak, and the surface covered with fine equal concentric striæ, besides four or five rugæ or varices of growth. The posterior side (at least we must suppose this to be the posterior side from analogy with other species of *Nucula*,—the beak is however extravagantly raised ;) is gently concave without a distinct lunette, the posterior and ventral margins arched; the whole figure is triangular.

The interior shews a flat hinge-plate, broadest beneath the beak, but with no cavity for a ligament, which must therefore have been external, though no fulcra are visible. The teeth are numerous and V-shaped, extending far down the posterior hinge-plate, and half-way down the anterior side. They are either absent or very small immediately under the beak.

This beautiful species exactly resembles at first sight one common in the Lower Silurian rocks of Wales, the *C.* (Nuc.) *varicosa*, Salter, and it is difficult to say how they differ. But while the Canadian fossil is a solid shell, the British species is a very thin one, and it is the interior cast of the one that resembles the outside of the other.

Locality.—Allumette Islands.

ORTHIS TRICENARIA, Conrad.

Decade I. Plate 9.

Genus *Orthis*, Dalman. Mollusca Brachiopoda. Family Orthidæ. Shell punctate, squarish, rounded, or transversely oblong (the hinge-line generally narrower than the shell), radiately striated or plaited, convex in one or both valves; hinge-line with a fissure open in both valves*; dorsal valve with divergent short teeth, and a simple cardinal process between them; muscular impressions roundish, and circumscribed in the dorsal valve.

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* In *Orthisina* and *Streptorhynchus* the fissures are closed. These are regarded as subgenera of Orthis by some authors.

Specific character.—O. rotundata pollicaris, valvâ dorsali planâ, ventrali gibbâ cardine, in latitudine testam æquante ; areâ magnâ subcurvâ ; foramine angustissimo. Costæ radiantes convexæ, circiter 30, *interstitiis angustissimis in valvâ dorsali sœpe filiferis ; striis transversis inconspicuis.*

Synonym.—O. tricenaria, Conrad, 1843. Proc. Acad. Nat. Hist. Soc., vol. i., p. 333. Hall's Pal. New York, vol. i., p. 121, plate 32, figure 8.

There could scarcely be better examples of specific character, as distinguished from mere variability, than are exhibited by four shells, two American and two British, among the large plaited Orthides of the Lower Silurian rocks. Of these, *Orthis tricenaria*, the subject of our plate, is precisely analogous to the English form, *O. actoniæ*, Sowerby, while *O. pectinella*, of Conrad, another American species, with numerous varieties, equally well represents the *O. flabellulum* of Snowdon.

Yet while all these species so much resemble one another that they might easily be confounded, each is distinguished by characters as neat as they are constant. *O. Actoniæ*, Siluria, 3d edition, p. 209, fig. 32, has few strong angular plaits, frequently bi- or tri-furcate at their ends, and the ventral or receiving valve is the convex one, the dorsal being concave. In *O. flabellulum* the reverse takes place, or the larger ventral valve, although prominent at the beak, being much flattened and actually concave, while the convex valve is the dorsal one. This difference is constant, while the fewness of the ribs in both distinguish them from the variable *O. calligramma* of Dalman, which has both valves gently and equally convex.

The same relative differences are observable in the two American species above quoted. *O. tricenaria* has the ventral valve the large one, and the other flat or even concave, while *O. pectinella* possesses a well-defined convex dorsal valve and a concave ventral valve, the beak of which is nevertheless prominent, as it is in *O. flabellulum*. Both again are distinct from the *O. plicatella*, which represents in America the *O. calligramma* of Europe, and, like it, has both valves convex.

O. tricenaria is of a semi-oval or even subtrigonal form when young, and in age is subquadrate, from the greater extension of the front than the sides, with length and breadth very nearly equal. Dorsal valve (fig 1), flat, concave at the beak, its hinge-line straight, produced into very short ears; ventral valve (fig. 2), strongly convex, even gibbous, its beak much elevated, but not at all incurved ;

area oblique, broad-triangular (about 140°); foramen almost linear, continued quite to the apex.

Surface of both valves closely radiated by about thirty convex, rod-like ribs, with narrower interstices, the ribs quite simple in the ventral valve, but interlined in the upper or dorsal valve by fine regular threads. All are crossed by delicate, inconspicuous striæ of growth. Old specimens are antiquated near the margin. The shell is thin; the interior is deeply scored, for some distance from the margin, by conspicuous furrows between the ribs; each rib is impressed by a median groove.

The space for the muscular impressions in the ventral valve (fig. *3a)*, is moderately large, rhomboidal, bilobed at the base, circumscribed by external blunt ridges, and divided by a very slight median one. The hinge-plates are very short, and diverge at about 80°. The ovarian spaces *(b)* are well marked.

The interior of the dorsal valve (fig. 4), with the muscular impressions very strongly marked *(b, c)*, shews them divided by a broad, rounded ridge. The brachial processes or hinge-teeth *(a)* are very short, diverging at 50°, and with a linear central tooth (cardinal process), which bisects the narrow foramen, and bends backward with the area. The ribs shew very strongly in the interior, fully half-way up the shell.

The area in the dorsal valve is flat, and forms an angle of 50° with the valve itself: that of the ventral valve is inclined at about 70°; it is very little curved. The two areæ meet at about 120° in the young shell, and about 90° to 100° in the adult.

A great advance was made in the classification of the Brachiopoda by Dalman, when he established the genera Orthis and Leptæna for the numerous Silurian species he was acquainted with. And little has since been done for the family of the *Orthidæ*, except the subdivision of the former genus, and the separation from both of the flat, semicircular forms now known under the name of *Strophomena*. The three genera are clearly separable, if account be taken of the general habit, as well as of the characters of the hinge and muscular impressions, for while *Leptæna* has the valves involute, and the muscular impressions of the entering valve greatly elongated, *Strophomena* and *Orthis* have these four impressions subquadrate and arranged in a circumscribed group, *Strophomena* being further distinguished from *Orthis* no less by its expanded flat form, than by the large bilobed cardinal process between the teeth in the dorsal valve. In *Orthis* the process is simple, often linear, and the two teeth

divergent at a much less angle. The hinge-line of *Orthis* is variable in width, often considerably less than that of the shell. In *Strophomena* it is always as wide as the widest part of it. *Orthis* has generally one, sometimes both valves convex. *Strophomena* has both valves flattened, and generally one bent over the other. And while the impressions of the blood-vessels in the mantle of *Orthis* are radiating and but little curved upwards on the sides, those of *Strophomena* take a wide upward bend, and quite encircle the ovarian spaces.

The range of the three genera, thus defined, is somewhat different. *Orthis* is the earliest, beginning in the period of the Lingula flags, and reaching upwards by one or other of its subgenera to the Permian rocks. *Leptæna* began not quite so early, in the Llandeilo flags, but maintained its position till the Oolitic period; while *Strophomena*, more restricted than either, commenced apparently at the same period with *Leptæna*, but is not known later than the Devonian epoch. Some authors of repute (M'Coy, Woodward, etc.,) regard *Strophomena* and *Leptæna* as mere subgenera, but I prefer, as Mr. Thomas Davidson has done, to give them each generic rank.

The separation of the four subgenera,—Orthis (Dalman), Orthisina (D'Orbigny), Streptorhynchus and Platystrophia of King, is quite convenient, and of geological value. The range of the true Orthis is the most extensive, and the possession of an open triangular foramen in one or both valves, distinguishes it from Orthisina, a Lower Silurian form. In this both valves have a closed deltidium, a small circular hole only being left in the apex of the larger valve. *Platystrophia*, which has the form of a Spirifer, and an open foramen in both valves, is Silurian only, while *Streptorhynchus*, (which, in the form of the teeth and hinge-plates) is most like *Orthisina*, has a wide area, and is attached by the twisted beak. It is an irregular form, characteristic of the Carboniferous and Permian strata.

Locality.—Pauquette's Rapids, in tolerable plenty, with *Strophomena planumbona* and *S. filitexta* (*S. alternata* seems to be absent). *Rhynchonella increbescens* and *Pentamerus* (*atrypa*) *hemiplicatus* of Hall are here. They are both Trenton fossils, and there are one or two other species of *Rhynchonella* and of *Orthis*, of smaller size.

Receptaculites.

Decade I. Plate 10.

Generic character.—Receptaculites, Defrance. Sub-kingdom Protozoa. Order Foraminifera. Family Orbitolitidæ. An infundibuliform disk, composed of vertical cells in a single series, having rhomboidal thickened apices at each extremity: the casts of these cells within are thick cylindrical columns (of sarcode) connected by transverse stolons at their upper and lower ends; and by smaller ones in the middle of the columns.

The clearing up of the affinities of a single doubtful fossil is never barren of good results, since it may tend to throw light on other forms as little understood, as well as upon the conditions under which the organisms lived and were imbedded. And if, as in the present instance, it should be rendered probable that an extinct form was of much greater size and importance than its living congeners, the excessive development in earlier times of a type now existing, is a fact quite as significant in its bearing on the history of organic life on the globe as the absolute replacement of one group by another in geological time.

The genus *Receptaculites* has long been known, having been described and figured by Defrance so early as 1827, and quoted by De Blainville from the Devonian rocks of Belgium. It is known in the Silurian strata of Australia and in the northern parts of the American continent, but has not yet been detected in strata of that age in Britain.

It has been referred to plants, and doubtfully to corals, but still remains where it was first placed, among the group of "Incertæ Sedis." It does not seem to have occurred to naturalists* that a form frequently five inches in diameter and not less than an inch in thickness could be referable to the group of Foraminifera, and be allied not very distantly to the genus *Orbitolites*. But the excellent figures and elaborate descriptions by Dr. Carpenter of this group of the Foraminifera, and especially of some large species from Australia and the

* Except my friend Mr. T. R. Jones, who, some years back, perceived the analogy in form, but neither he nor myself at that time took any further notice of it. I had forgotten his observation when Dr. Carpenter's memoir appeared. It is due to him to recall it.

South Sea Islands, shew a great resemblance to our fossils, which on closer study becomes more striking; and I am induced, notwithstanding slight differences of structure, to regard *Receptaculites* as belonging to the same family, and as having a greater resemblance to the complex than to the more simple forms of the Orbitolitidæ.

It will be desirable first to shew what is the structure of Orbitolites, as given by Dr. Carpenter in his memoir, "Trans. Phil. Soc.," volume for 1856. If the enlarged figure with vertical and horizontal sections in his plate 5, fig. 6, be taken, as he intends them, to shew the general structure of a compound Orbitolite, it will be seen that the greater part of a vertical section through a disk is occupied by the simple columnar cells which form the basis of the whole structure, and which are produced in successive rings around the globular central chamber. The cells of one ring alternate with those of the next, and form, when the superficial layer is removed, or as seen in horizontal section, a quincunx arrangement of circular cavities. Each ring of cells is connected with the next by small perforations giving passage to the minute stolons of sarcode, and of these there is only one to each cell in the simple forms, but they are numerous in the more complex varieties. Besides these small connecting stolons which link together the cells of one circle with those of the next, there are others, concentric ones of large size, which connect the cells laterally, there being in the complex form an upper and a lower great concentric stolon running along the top and the bottom of all the columns. It is from these stolons that the superficial segments take their rise, and not directly from the crown of the large cell itself. In the simpler type there is no distinction into superficial and median cells, nor any great concentric stolons above or below, the connecting pores being placed about the middle of the large cells, which are often bent in shape. (See figures 4, 5, 7, in plate 5 of Dr. Carpenter's paper.)

In the Orbitolites of the Paris basin there is not that clear separation of the superficial from the columnar cells which exists in the other form;—the upper or outer cells being in fact the upward or downward continuation of the columns themselves, and only separated from them by the large stolons before described. (See his plate 6, figs. 10, 11.)

Receptaculites.—In the possession of great columnar cells, with large connecting stolons above and below, and with several smaller ones on the sides of the columnar cells, our fossil agrees with the complex forms described by Dr. Carpenter, but (as in the Parisian

Orbitolites), there are no superficial cells proper, although the cavity has swelled out and been extended at the terminations of the columns above and below, so as to give the appearance of a superficial stratum. It will be seen by the description that this form most nearly illustrates our fossil.

R. OCCIDENTALIS, N. sp.

Plate X. Figs. 1–7.

Synonym.—R. Neptunii? Hall, Palæontology of New York, vol. i., page 68, plate 24, figure 3.

Specific character.—R. magnus, 5–6, pollicaris, vix infundibulatus, crassus, cellulis verticalibus rectis cylindricis, apicibus supra rotundatis convexis, subter planis, rhomboideis granulatis.

Discoid, from four to six inches broad, and from half an inch to an inch in thickness; the limb gently convex above, but rather suddenly indented and cup-shaped in the middle, from which the rows of cells radiate in curved lines, crossing like the engine-turned ornament of a watch. The thickness of the disk near the centre is but little, but this increases rapidly towards the margin, becoming in some cases half an inch thick at twice that distance from the centre. The cavities of the cells themselves (in the fossil filled up with silex) are not above a line and a half broad in the largest specimens. They are rhomboidal on the lower surface (figure 5); on the upper (figure 3) they terminate in a convex boss and have wide openings between, but are connected by four lateral processes with the adjoining cells.

A cross section, as in the right-hand portion of fig. 1 (fig. 6*c*) shews the columns round (*a*) and with interstices nearly equal to their own diameter, and a lateral view (figure 6) shews the columns with their bases (*a*) expanded, so as to leave but narrow linear interstices on the lower surface*. At a short distance above this they give birth to four connecting processes or stolons (*c*), as above described. The columns are thence cylindrical, and nearly their own diameter apart. In one of the specimens there are several intermediate small connecting stolons along the columns (figure 4*a*), and this is important in comparing the fossil with the recent Orbitolites.

* Figures 1, 4, 5, 6, 7, are reversed, being placed upside down on the plate. Figures 2, 3, shew the upper surface of the cup.

The upper termination of the cells (fig. 6*c*) again expands, so as to form broad and closely placed tesseræ, with only small cavities between them. These were of course, if the fossil be a Foraminifer, filled up with solid calcareous matter, now removed.

One character in particular which serves to connect the fossil with its living analogue is the very considerable space occupied by the animal matter—now solid spaces filled with silex—both on the upper and lower surfaces.

It forms, as above noted, rhomboidal plates on the *lower* surfaces, which plates are somewhat imbricated; and the concavities within them (not distinct cells, as in compound Orbitolites,) communicate with each other at one or more of the angles (figure 7) very much in the way shewn by a section of Orbitolites (see Carpenter, l. c., plate 6, figs. 1, 2), while the intervening calcareous walls are linear and thin. (Sometimes, as in *R. australis*, figs. 8, 9, these basal plates are lobed.)

If, instead of comparing Receptaculites with the Orbitolites, we should suppose it related to any of the millepore corals, or still more probably to such a form as that of the purple organ-coral (*Tubipora musica*), the reverse of all this would be the case. There should be a calcareous plate or epitheca on the lower surface, from which the tubular corallites would spring, and the walls of these latter, however thin, ought to be visible in the transverse section, which we do not find to be the case in slices of the columns viewed by transmitted light. Again, the upper extremity of the tubes should be open, not closed by convex plates as in the fossil, since such could only be the case when the walls of the coral-cells were so greatly thickened as nearly to close the mouth, while we have seen that in the fossil the corresponding part expands, and is covered over by a definite and often lobed plate, to all appearance continuous with the walls of the cells.

If any analogy be suspected between Receptaculites and such Palæozoic corals as Halysites (the chain-coral), or with Syringopora, there should, besides the characters above mentioned, be indications of transverse plates which have never yet appeared.

I believe all this applies equally to the *Receptaculites Neptuni* of the Devonian rocks of Belgium, but there is some appearance of a thin investment of the columns in transverse sections of that species which requires further investigation. And as it is of a deeply infundibuliform shape, there is of course a possibility that it and the other Receptaculites may be very regularly formed sponges; but I

have the greater satisfaction in the above view of the affinity, because, on explaining the specimens to Dr. Carpenter, I found that he entirely agreed in it. After pointing out several objections that might be made, he shewed me that there was in nearly every point a close coincidence in essential structure between Receptaculites and Orbitolites, the difference being only in the giant size of the cells in this the most ancient of Foraminifera.

Locality.—Plentiful in the limestone of Pauquette's rapids. The Corals and Crinoidea which accompany it are: *Petraia* (2 species), *Favosites lycopodites (?)* or *lycoperdon*, with the Crinoid *Schizocrinus nodosus*, and a species of *Glyptocystites*, the latter more rarely.

R. australis, N. sp.

Plate X. Figure 8–10.

Specific character.—R. magnus, expansus, cellulis verticalibus subcylindricis incrassatis, apicibus subter convexis, lobulatis.

Under this name a curious species of the genus is figured, for the sake of comparison, from the Silurian limestones of New South Wales. Communicated by the Rev. W. B. Clarke.

It is remarkable as having the expanded apices of the columns on the lower surface lobulated in larger or smaller divisions, which all seem to radiate from a central boss. And this arrangement is quite different from the merely granulated surface observable in the *R. occidentalis* (figure 6).

The upper surface too (figured as the lower in the plate, figure 8), is curiously lobed beneath the surface. Figure 10 represents a portion of two columns, broken off near the base, and viewed from within.

Locality.—Upper Silurian limestone of Yarradong, between the Yass plains and the Murrumbidgee river, New South Wales, a locality rich in Upper Silurian forms, Tentaculites, Favosites, Pentamerus, Ormoceras, Trochonema, Rhynchonella, &c.

J. W. SALTER.

February 28th, 1859.

C. R. Bone del — W. Sowerby sc.

Maclurea Logani. Salter

PLATE I.

Maclurea Logani (page 7).

Figure 1. *Maclurea Logani.* Natural size. Lower or umbilical surface.

" 2. A younger specimen, with the operculum in place.

" 3. Upper view of same specimen, shewing the false umbilicus or concealed spire. This specimen has suffered some injury, and has a deep concentric furrow.

" 4, 5, 6. Exterior, inside and lateral views of an old operculum, with the apophyses for muscular attachments, *a*, *b*.

Fig. 1-3. Raphistoma lapicida. Salter.
. 4. ——— ——— aperta. id.
. 5-7. Helicotoma planulata. id.
Fig. 8. H. planulata var muricata.
. 9. 10. H.? spinosa. Salter.
. 11-14. H. larvata. id.

C. R. Bone del^t. W Sowerby sc^t.

PLATE II.

Raphistoma lapicida (page 12).

Figure 1. *Raphistoma lapicida.* Side view, with mouth.
" 2. —— ——. Spire of ditto.
" 3. —— ——. Base of ditto.

Raphistoma aperta (page 12).

" 4. *Raphistoma aperta.* Upper, lower and side view.

Helicotoma planulata (page 14).

" 5. *Helicotoma planulata.* View of the spire.
" 6. —— ——. Same specimen; under view.
" 7. —— ——. Do. side view.
" 8. —— ——. Var. *muricata.*

Helicotoma ? spinosa (page 15).

" 9. *Helicotoma ? spinosa.* Slightly magnified; the natural size is indicated by the cross lines.
" 10. Under view of the same, also magnified.

Helicotoma larvata (page 15).

" 11-13. *Helicotoma ? larvata.* Upper, under and side views.
" 14. —— ——. The same species, encrusted by a sponge (*Stromatocerium rugosum*).

Ophileta compacta, Salter.

del.t W. Sowerby sc.t

PLATE III.

Ophileta compacta (page 16).

Figure 1. *Ophileta compacta.* Internal sandstone cast; only a portion of one whorl is left. Internal cast, sandstone, reversed, and shewing the flat or umbilical surface. *c*, the inner basal angle; *b*, the outer basal angle; *a*, the upper angle or keel. The convex dome-like cast of the deep cup-shaped spire shews distinctly, as the whorls are broken away.

" 2. Cast of lower or umbilical surface.

" 3. Exterior of upper or concave side. *a*, the outer angle or keel; *d*, the inner upper angle. A gutta-percha mould, taken from a cast of the upper surface, representing therefore the true shell.

1. Murchisonia serrulata. Salter.
2-4 M. helicteres. id.
5. 6. M. bicincta. Hall.
7. M. ——. var. perangulata. id

C. R. Bone del.t W. Sowerby sc.t

PLATE IV.

Murchisonia serrulata (page 20).

(Not *serrata*, as in page 20.)

Figure 1. *Murchisonia serrulata.* Natural size; 1*, a portion magnified.

Murchisonia helicteres (page 21).

" 2. *Murchisonia helicteres.* A normal specimen.

" 3, 3*a*, 4. —— ——. The same species, irregularly uncoiled. The sutural edge on the uncoiled whorl is indicated at *s*.

Murchisonia bicincta (page 19).

" 5, 6. *Murchisonia bicincta*, Hall. Ordinary large variety.

" 7. —— ——, —. Variety with more angular whorls, and without the upper keel. (Var. *perangulata*, Hall.)

Fig. 1. Murchisonia gracilis Hall.
2. 3 ———— ventricosa. id

C. R. Bone del.t W. Sowerby sc.t

PLATE V.

MURCHISONIA GRACILIS (page 22).

Figure 1. *Murchisonia gracilis*, Hall. The cast or body-whorl a good deal broken away, and shewing the inner reflected lip.

" 1*a*. An enlarged whorl, to shew the lines of growth and the smooth band.

MURCHISONIA VENTRICOSA (page 23).

" 2. *M. ventricosa*, Hall. Of large size. The body-whorl here is also broken away; hence the pillar-lip, *p*, and the base of the whorl, *b*, are more prominent and curved than they should be. At *s* a slight ridge, just above the suture, is sometimes visible.

" 2*a*. Shews the moderately arched lines of growth.

" 3. A smaller specimen, less elongate than usual. The position of the band high up, near the sutures, is contrasted in this species with that of *M. gracilis*, figure 1.

GEOLOGICAL SURVEY OF CANADA.

DECADE 1. Pl. 6.
LOWER SILURIAN
(Trenton)

Fig. 1, Cyclonema Halliana. Salter.
2 ——— semicarinata id
3. Trochonema umbilicata Hall

Fig. 4. Eunema strigillata. Salter
5. ——— ? Pagoda
6. Loxonema Murrayana. id

C. R. Bone delt

W. Sowerby sc.

PLATE VI.

Cyclonema Halliana (page 26).

Figure 1. *Cyclonema Halliana.* Natural size.

Cyclonema semicarinata (page 27).

" 2. *Cyclonema semicarinata.* Natural size; 2*a*, 2*b*, front and back views, more enlarged.

Trochonema umbilicata (page 27).

" 3. *Trochonema* (Pleurotomaria) *umbilicata*, Hall. Three views of one specimen.

Eunema strigillata (page 29).

" 4. *Eunema strigillata.* Two specimens, natural size; 4*a*, upper part of whorl, magnified to shew the dichotomous striæ.

Eunema? pagoda (page 30).

" 5. *E? Pagoda.* Natural size.

Loxonema Murrayana (page 31).

" 6. *Loxonema Murrayana.* An unique specimen, imbedded in limestone.

Fig. 1–4. Cyrtoceras falx. Billings.
5–6. [illegible] Billingsii [illegible]

C. R. Bone del.t

W. Sowerby sc.t

PLATE VII.

CYRTOCERAS FALX (page 32).

Figure 1. *Cyrtoceras falx*, Billings. Side view and section of the larger end, the siphon on the outer (ventral) side of the curve.

" 2. Section (with siphuncle) of a more compressed form, the compression partly due to pressure. The tube becomes more and more cylindrical in age.

" 3, 3*a*. A younger specimen, from the Ottawa limestone.

" 4. A worn specimen, shewing the close septa.

CYRTOCERAS BILLINGSII (page 33).

" 5. *Cyrtoceras Billingsii* (*C. lamellosum*, Hall). Side view. 5* is the section at the larger end; 5** of the smaller cylindrical end—the siphon external.

" 6. A younger specimen, with closer lamellæ of growth.

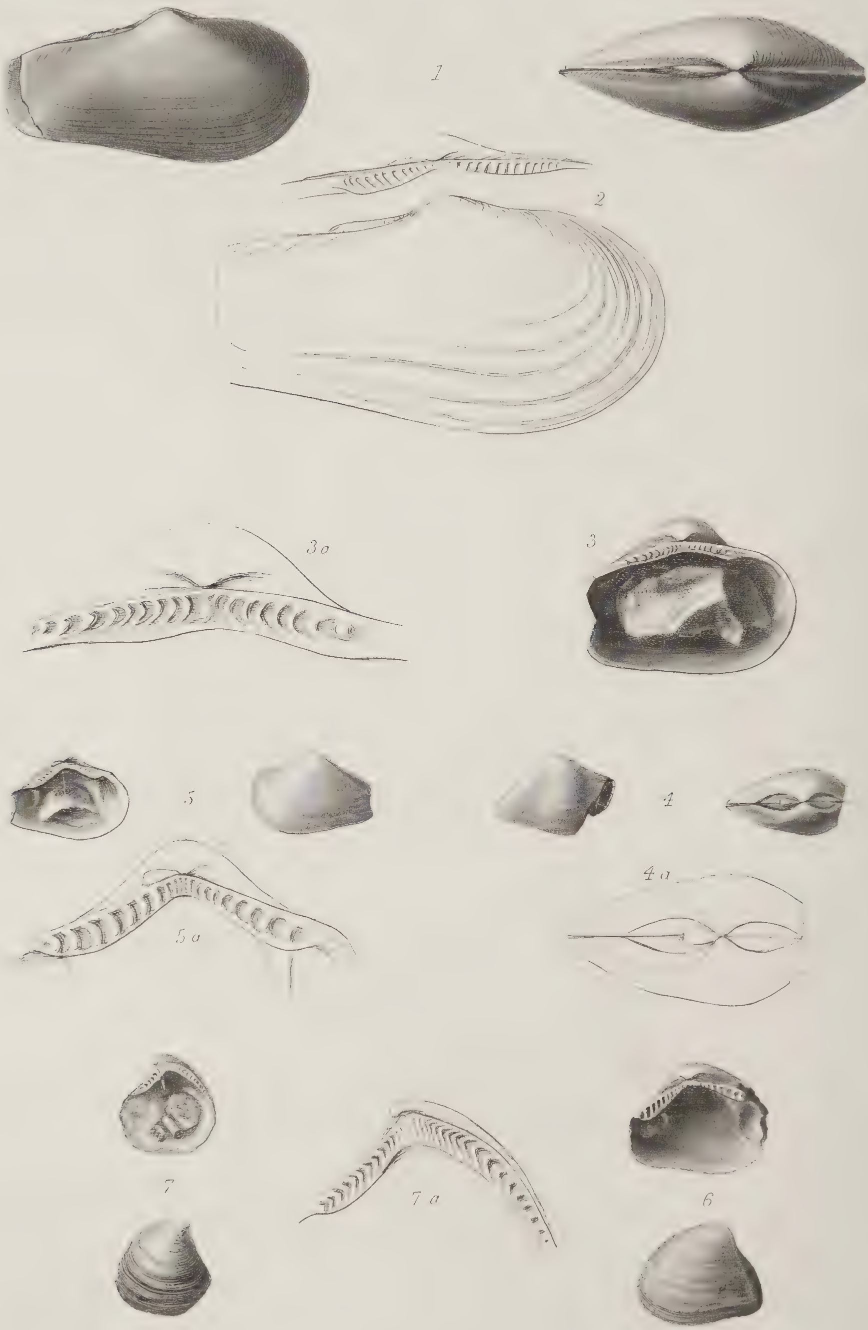


Fig. 1. 2. Ctenodonta nasuta. Hall. sp
3 ——— Logani. Salter.

Fig. 4. 5 C contracta. Salter.
6. gibberula. id
7. C? astartœformis id

C. R. Bone del[t] W Sowerby sc[t]

PLATE VIII.

Ctenodonta nasuta (page 35).

Figure 1. *Ctenodonta nasuta*, Hall. Natural size.

" 2. —— ——, —. Large specimen, with external ligament and hinge-teeth.

Ctenodonta Logani (page 36).

" 3. *Ctenodonta Logani.* Interior of left valve. 3*a*, the hinge enlarged.

Ctenodonta contracta (page 37).

" 4. *Ctenodonta contracta.* Var. with posterior sinus well marked. 4*a*, enlarged, to shew ligament.

" 5. —— The same, with the sinus obsolete. 5*a*, the hinge enlarged, the muscular impressions deep.

Ctenodonta gibberula (page 38).

" 6. *Ctenodonta gibberula.* Interior and exterior of the *left* valve.

Ctenodonta astartæformis (page 39).

" 7. *Ctenodonta? astartæformis.* Left valve, outside and interior. 7*a*, the hinge-line magnified.

1

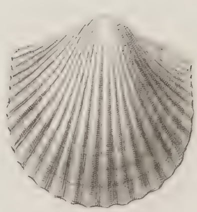
3

b a

4

a b c

2



C. R. Bone del.

W. Sowerby sc.t

[illegible]

PLATE IX.

ORTHIS TRICENARIA (page 39).

Figure 1. *Orthis tricenaria*, Conrad. Both valves closed. Dorsal view.

" 2. The same specimen; ventral view.

" 3. Interior of the ventral valve, shewing the muscular impressions (*a*), and the ovarian spaces (*b*).

" 4. Interior of the dorsal valve. *a*, the teeth or brachial processes—the small linear cardinal process is seen between them. *b*, *c*, the quadruple muscular impressions

GEOLOGICAL SURVEY OF CANADA

DECADE 1. Pl.10.
LOWER SILURIAN
(Trenton)

1–7. Receptaculites occidentalis. Salter.
8–10. R. australis. id.

C. R. Bone del.t W. Sowerby sc.t

PLATE X.

RECEPTACULITES OCCIDENTALIS (page 45).

Figure 1. *Receptaculites occidentalis.* Upper view of a fragment of a large specimen. At *a*, a rubbed portion exposes sections of the cylindrical columns.

" 2. A more weathered specimen, upper side shewing the convex ends of the columns.

" 3. Cupped central part of a specimen.

" 4, 5. Detached fragments reversed, the upper side downwards, shewing the rhomboidal bases to the columns. 4*a* ditto., shewing the connecting stolons. 4*b*, the same magnified.

" 6. One or two columns magnified, reversed. *a*, the rhomboidal granulated space; *b*, the connecting basal stolons; *c*, the apices of the columns; *d*, the interstices between them; 6* is the base of one of the columns, more highly magnified.

" 7. Shews a portion of the lower surface polished. Some of the rhomboidal spaces are connected by the stolons with each other.

RECEPTACULITES AUSTRALIS (page 47).

" 8. *Receptaculites australis*, Salter. A new Australian species, introduced for comparison. Lower surface, with the lobed bases of the columns.

" 9. Some of the columns magnified. The stolons are not clearly seen in this specimen.

" 10. View from the inner surface of these lobed bases, shewing the ramifications of the sarcode highly magnified.

GEOLOGICAL SURVEY OF CANADA.

SIR W. E. LOGAN, F.R.S., DIRECTOR.

FIGURES AND DESCRIPTIONS OF CANADIAN ORGANIC REMAINS.

DECADE II.

GRAPTOLITES OF THE QUEBEC GROUP.

BY

JAMES HALL.

MONTREAL: DAWSON BROTHERS.

LONDON, NEW YORK, AND PARIS: BALLIÈRE.

1865.

PREFACE.

The Graptolites of the Quebec group, which are the subject of the present Decade, were first discovered at Point Lévis in 1854, and were then confided for investigation and description to Professor JAMES HALL of Albany, the distinguished Palæontologist of the Geological Survey of the State of New York. This was prior to the appointment of Mr. E. BILLINGS as Palæontologist to the Canadian Survey, in 1856. After a preliminary notice communicated by Professor HALL in 1855, extensive additions were made to the collection of Canadian Graptolites, which were placed in his hands; and in 1858 descriptions by him of nearly all the species here figured were published in the Report of Progress of the Geological Survey of Canada for 1857, but without illustrations. Figures of one of the species were however published in the *Canadian Naturalist* for June 1858; but various accidental difficulties having occurred in the preparation and engraving of the plates, the publication of the Decade has been delayed until the present time.

It is to be remarked that although the name of Decade, under which Parts I, III, and IV were published, is still retained, this monograph is illustrated by not less than twenty-three plates. These are all from excellent drawings by Mr. R. P. WHITFIELD of Albany. Twenty-one of them were engraved on steel by Mr. JAMES DUTHIE of New York, and the remaining two were lithographed by Mr. F. J. SWINTON of Albany.

W. E. LOGAN.

GEOLOGICAL SURVEY OFFICE,
Montreal, December 1864.

TABLE OF CONTENTS.

CHAPTER I.

INTRODUCTION.

CHAPTER II.

SUPPLEMENT.

ERRATA.

Page 146, 6th line from bottom, and page 147, 4th line from bottom, for Reteograptus read Retiograptus.

Page 147, second line from bottom, read " The frond *four* times enlarged."

GRAPTOLITES OF THE QUEBEC GROUP.

CHAPTER I.

INTRODUCTION.

§ I.—NATURE AND FORM OF GRAPTOLITES.

Until recently the graptolites were, with two or three exceptions, known only as simple, straight, or slightly curving linear stipes or stems, usually lying in the same plane upon the slaty laminæ in which they were imbedded. Nearly all these were evidently fragmentary, and, though varying somewhat in their proportions, rarely exhibited anything that could be regarded as the commencement or termination of their growth or development. These bodies, in their flattened condition, present a range of serratures either on one or on both sides of the stipe; and seldom preserve more of their substance than a carbonaceous or corneous film or test of extreme tenuity. Under more favorable circumstances, these serratures are discovered to indicate the apertures of cellules, symmetrically arranged in reference to each other, and to the axis of the linear stipe. Others show parallel entire margins, with transverse indentations across the central portion of the stipe. This appearance we now know to be due to the direction of the pressure upon the body exerted at right angles to the cellules, and which will be explained in the sequel.

The earliest opinion regarding these fossils was that they were of vegetable origin; and they have been thus considered by some authors even at a very late period. Subsequently, they were referred by Wahlenberg, and after him by Schlotheim, to the Cephalopoda, being regarded as extremely slender orthoceratites. This opinion may have received support from specimens in such condition as *G. scalaris*, where the indentations are limited on each side by a continuous margin; but in such as present a single or double series of marginal serratures, the analogy seems very remote. Professors Geinitz and Quenstedt advocated the same view at a much later date; though it has since been abandoned by these authors, from more extended investigations.

Professor Nilsson first suggested that graptolites were Polypiaria, belonging to the family Ceratophyta. Dr. Beck of Copenhagen regarded them as belonging to the group Pennatulidæ, of which the Linnean *Virgularia* is the most nearly allied existing form. Sir Roderick Murchison has adopted this view of the relations of the graptolites, in his Silurian System.* General Portlock has fully recognized the graptolites as zoophytes, and has pointed out their analogy with *Sertularia* and *Plumularia*.

The relations of graptolites with the Cephalopoda had already been fully disproved by M. Barrande (in the first chapter of his "*Graptolites de Bohème*"), before the abundant materials for the refutation were discovered in the graptolites of the Quebec group; and most naturalists were already agreed in referring these bodies to the class of Polypi, to which they doubtless belong.

More recently, Mr. McCrady, of South Carolina, has published a paper on the "Zoological Affinities of Graptolites,"† in which he has endeavored to show the similarity of the graptolitic forms with the Echinoderm larvæ, as illustrated by Müller. There is certainly much resemblance between the enlarged figures of that author, and some forms of graptolites in the shales of the Hudson River valley; while some of the figures with central discs have a more remote analogy with certain forms from the Quebec group. Some of the toothed rods of the Echinoderm larvæ likewise bear a resemblance to the graptolites figured by Mr. Suess;‡ and there are still farther analogies pointed out by Mr. McCrady, which, however, may not be regarded as of equal value by the greater number of naturalists.

For my own part, although admitting the similarity of form and of some of the characteristics which were very kindly pointed out to me by Mr. McCrady, long before his publication, I cannot recognize the analogy sought to be demonstrated. The establishment of the fact that these toothlets or serratures are the extensions of true cellules, each one having an independent aperture, and communicating with a common canal, should offer convincing argument against these bodies being other than polyp-bearing skeletons. But, in following the extensive series of forms now presented to us, we have much evidence to show that some of these were attached to the bed of the ocean, or to other bodies; while the greater proportion of the species and genera appear to have never been attached to the sea-bottom.

It may not be easy to determine precisely the family to which these

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* Silurian System, page 694; and letter of Dr. Beck, pp. 695-6.

† "Remarks on the Zoological Affinities of the Graptolites, by John McCrady, made before the Eliot Society of Natural History of Charleston, S. C., at the meeting of July 15, 1857." [Extract from the Proceedings, vol. i.]

‡ Naturwissenschaftliche Abhandlungen. Vierter Band. Tab. viii and ix.

graptolitic forms should be referred; nor is it certain that the extensive series now presented can all properly be referred to a single family. General Portlock has suggested that these bodies may constitute "several genera belonging even to more than one order."* That they are true Polypi, I believe we shall be able to show, both from analogies already established by various authors, and also from their mode of development or reproduction as exhibited in some of the species.

The specimens which have usually been observed or represented are simple disconnected stipes, doubtless the dismembered or fragmentary portions of fronds, which, presenting in the different species great varieties of form and aspect when entire, are nevertheless composed of parts so similar that these fragments, though indicating specific differences, offer little clue to a knowledge of the entire form.

The name *Graptolithus* was established by Linnæus in the first edition of his "*Systema Naturæ,*" 1736, and applied by him to the straight or curved forms which are serrated (celluliferous) upon one side only, of which *G. sagittarius* has been regarded as the type.† The propriety of this term is more readily perceived in its application to the fragments of the stipes of monoprionidian forms than to the central portions of the body of the same. In the spirally-enrolled forms, or those with four or more stipes uniting in a central disc, as well as in the variously-branching forms, the analogy is not so perceptible.

Taking those species which, in the form of their cellules and in the separated fragments of the frond, would be referred to *Graptolites* proper, and tracing them, as we are now able to do in many species, to their perfect condition, we find a great variety of form and mode of growth. In the simplest of these we have two stipes diverging from a radicle, or initial point; and the parts remain so complete as to admit of no doubt

Fig. 1.

GRAPTOLITHUS PENNATULUS.

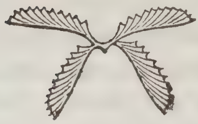
that this is the entire skeleton of the animal. The cellules near the base of the stipe are not so fully developed; while also those near the extremities have not reached their full dimensions, and the last one is sometimes barely perceptible, or just assuming its form from the common body. These characteristics are perceptible in the figures upon plates i, ii, and iii.

In the next stage we have four simple stipes diverging from an initial point, and all evidently entire, as shown in the development of the cellules.

* Geological Report on Londonderry, &c., p. 318.

† I shall elsewhere endeavor to show that *G. scalaris* is a diprionidian form exhibiting only one margin.

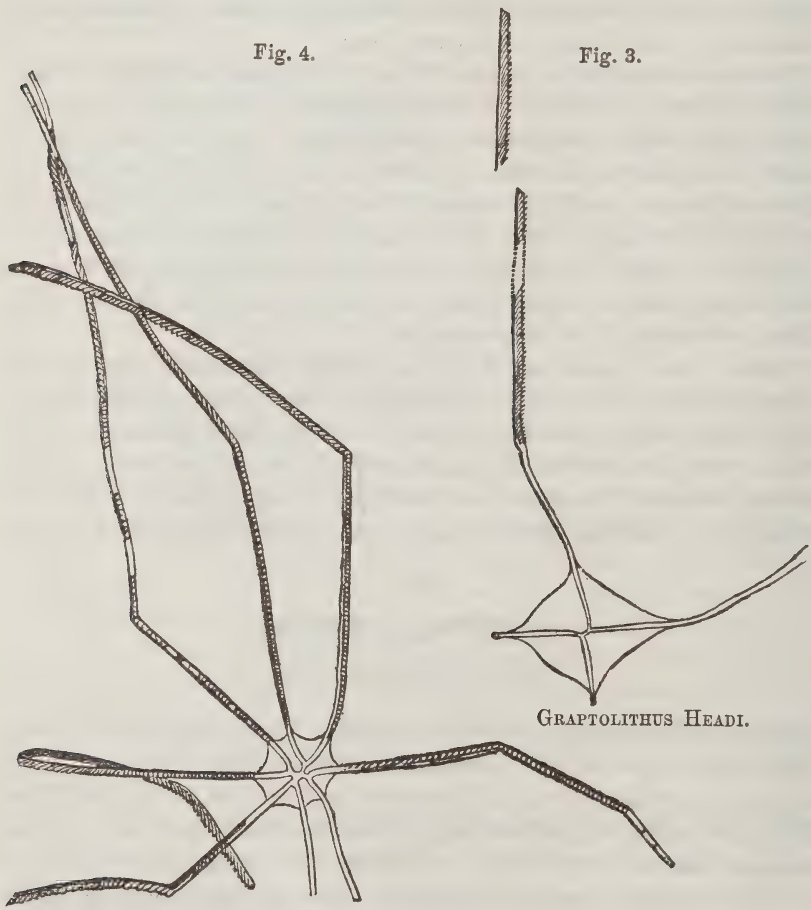
Fig. 2.



GRAPTOLITHUS BRYONOIDES.

In some species of this mode of growth, the bases of the stipes are united in a more or less expanded disc or cup of the same substance as the body of the graptolite. The form of this disc is shown on plates v, vi, vii, viii, and ix, and also in the accompanying figure of *Graptolithus Headi*.

Fig. 4. Fig. 3.



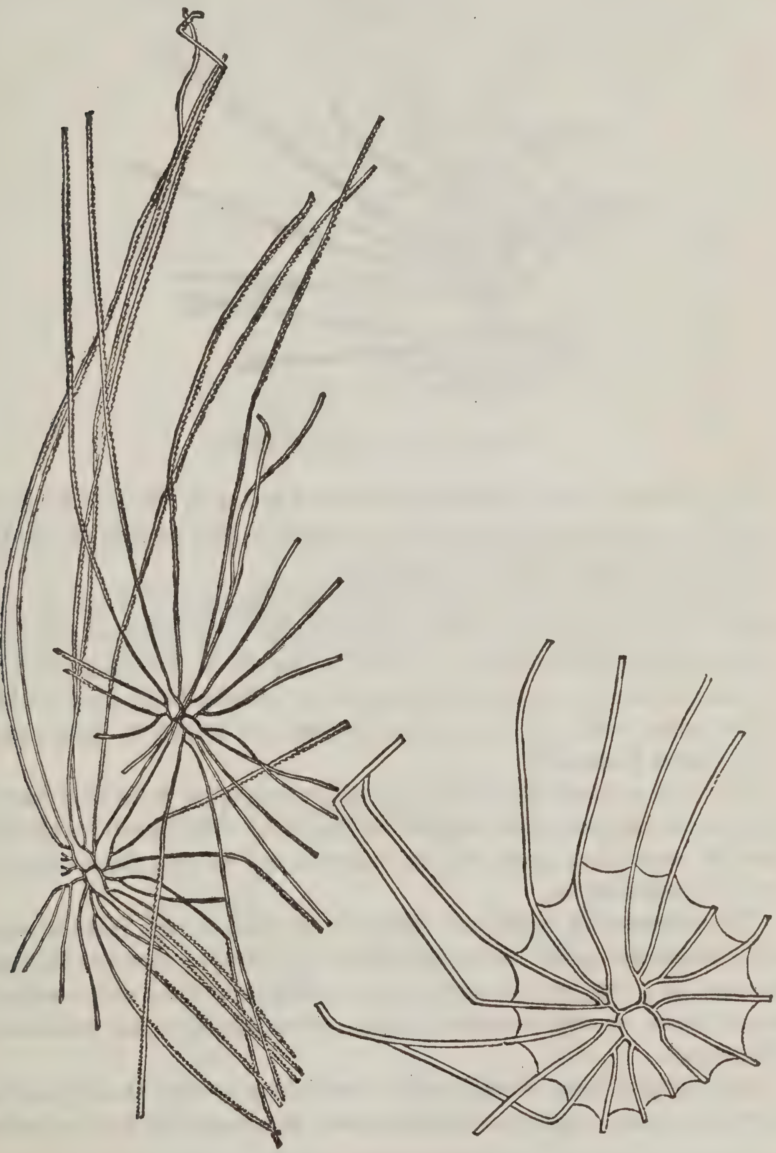
GRAPTOLITHUS HEADI.

GRAPTOLITHUS OCTOBRACHIATUS.

In a farther development in the same direction, we have fronds with eight simple stipes, which may or may not be united in a central disc, as in the accompanying figure.

In *Graptolithus Logani* we have numerous simple stipes united in a central disc or cup; while in some specimens otherwise precisely similar, we have no remains of the disc. In all these species the parts are disposed in a symmetrical and bilateral arrangement.

Figs. 5 and 6.

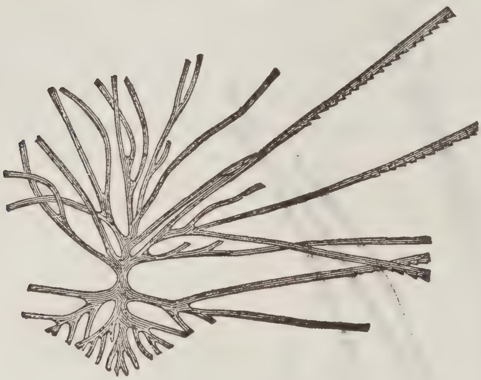


GRAPTOLITHUS LOGANI.

The stipes of this species do not bifurcate beyond the disc, and there

are no cellules below the last bifurcation. The number of stipes in different individuals varies from sixteen to twenty-five, so that this character cannot be made of specific importance. In another similar species without a central disc, from the Hudson River formation, we have above forty stipes, which do not bifurcate, so far as known, beyond the commencement of the cellules.

Fig. 7.



GRAPTOLITHUS MULTIFASCIATUS.

The separated and broken stipes referred by me to *Graptolithus sagittarius* * are probably of this species, occurring as they do in great numbers in the same beds in which this was found.

In other species with a similar general arrangement of parts, the main stipes are frequently bifurcated; the bifurcations beginning near the base, and continuing as far as the parts can be traced in the stone (fig. 8). In some of the species of this character the cellules begin near the base of the stipes, while in one species they are not known to exist except on the outer branchlets.

Thus far we trace these forms through what appear to be very natural stages in the progress of development of the parts, which are all constructed upon the same plan, presenting only natural, and we may almost say consequent modifications.

The character of stipes and cellules in all these is such that the separated fragments would afford no means of indicating whether the part belonged to a two, four, or eight-stiped species, or to those with numerous simple stipes, or with branching stipes, unless the fragment retained a bifurcation.

A variety of form is exhibited in the division termed *Dendrograptus*, in which we may conceive of the numerous stipes near the base becoming

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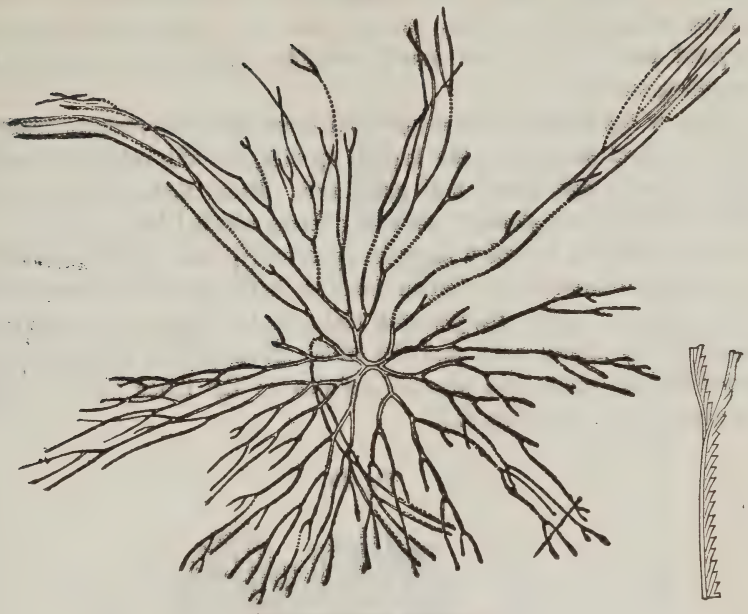
* Palæontology of New York, vol. i, page 272, pl. 74, fig. 1.

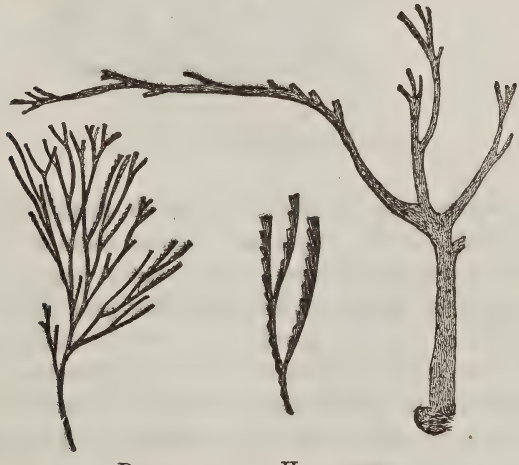
Fig. 8.



Graptolithus flexilis:
with a portion enlarged.

conjoined into one strong stem, with the bifurcating branchlets spreading above, and this stem probably fixed in the soil. We then have a representation of the typical forms of this genus, as in the accompanying figure, and as illustrated on plate xvii, figs. 8 and 9, of this memoir.

Fig. 9.



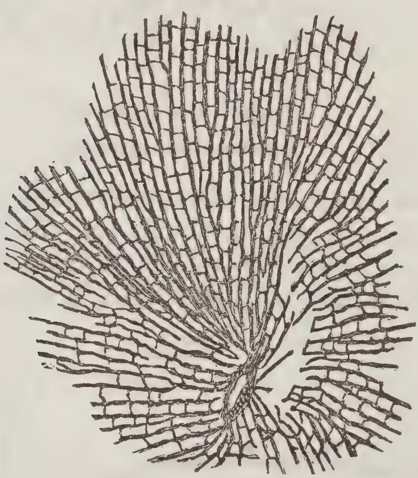
Dendrograptus Hallianus.

In this species, as shown in the enlargements of the branchlets, we have

a form of cellule similar to that in observed fragments of the ordinary species of graptolites. The cellules are very minute, and, from the frequent ramifications, this would probably always be recognized as a branching species.

Some of the forms of *Dendrograptus* have slender spreading branches, and less rigid stems than the typical species, but still retain the angular cellules, as in figs. 1 and 2 of plate xvii. From these we pass almost imperceptibly to the slender spreading forms which I have termed *Callograptus*, plate xix, in which there is, apparently, some slight modification in the form of the cellule; and on the other hand, there is an almost insensible gradation to the *Dictyonema*, plate xx, in which the branches are connected by lateral bars, and the whole developed in a flabelliform or funnel-shaped frond, with angular cellules on the inner margins of the branches. (Fig. 10, plate A.)

Fig. 10.



Dictyonema retiformis.

There are certain forms of graptolites, which, though possessing linear straight or slightly curving stipes and angular cellules, like the typical species, have yet a different aspect, and do not so naturally fall into the series. Among these we find *Graptolithus divergens* (fig. 11), where the bilateral relation of the parts is still shown, but the celluliferous stipes or branches are arranged on the two sides of a slender stipe or rachis, and diverge on each side from what appears to be the centre or initial point.

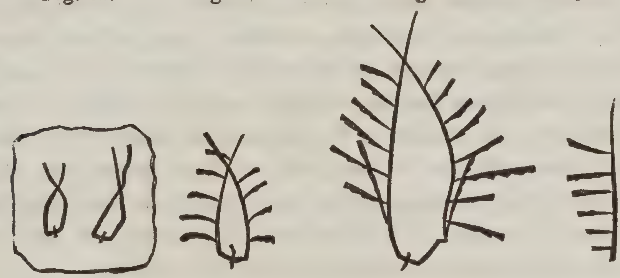
Different specimens show some slight variations of these characters, but not any essential differences.

Fig. 11.

Graptolithus divergens.

Another form, which we know only in small individuals, is illustrated in the following figures, which remind one of some forms of the recent genus *Crisia*.

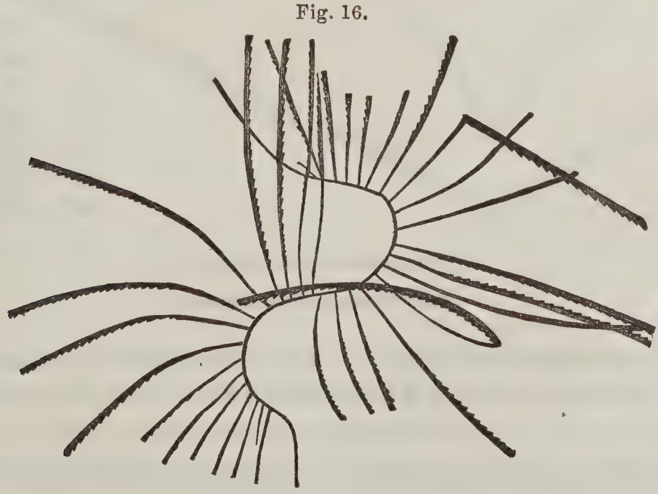
Fig. 12. Fig. 13. Fig. 14. Fig. 15.



(These figures are enlarged to twice their natural size.)

In another form with similar angular cellules, we have the following illustrations of the mode of occurrence of the species.

Fig. 16.



Graptolithus gracilis.

Fig. 17.

Fig. 18.

GRAPTOLITHUS GRACILIS.*

We have still another group, presenting some differences, more particularly in the development and form of cellules, than in their general form; and seeming in some species to unite the characters of those having a single range, with those having a double range of cellules. The simpler forms of this type are similar to the two-stiped forms of the first series; but in all those, whether of two, four, or more stipes, the cellules are developed on the upper side, or that side opposite to the initial point. In species like *G. sextans*, *G. divaricatus*, and others of this type, the cellules are on the lower, or same side with the radicle.

Fig. 19.

GRAPTOLITHUS DIVARICATUS:

and enlargement of cellules.

In the accompanying figure of *G. divaricatus*, the frond consists of two simple uniserrate stipes; and the same is true of *G. sextans*, except that

* The fig. 18 was theoretically constructed, but has since been verified by the discovery of a specimen having the same form and arrangement of parts.

it is united at the base for the length of a single cellule. In *G. furcatus* the stipes are conjoined for a distance of two or three cellules above the base.

In *G. ramosus*, as shown in the following figure, the lower part of the stipe, for a considerable distance, has a range of cellules on each side, parallel with the axis; and becoming bifurcate above, it presents two stipes or branches, each with a single range of cellules. All the species of this group have a peculiarity in the form of the cellules, which will be noticed hereafter.

Fig. 20.

GRAPTOLITHUS RAMOSUS.

These species, in their mode of growth alone, present forms which might be regarded as intermediate between the monoprionidian and diprionidian groups; though the typical forms, *G. pristis* and allied species, never show any tendency to a division of the parts of the stipe; and we shall observe, as we progress, that these forms are connected with other differences of structure.

Fig. 21.

GRAPTOLITHUS PRISTIS.

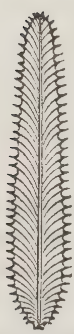
The species of this type (*Diprion* or *Diplograptus*) are simple linear or

sub-linear stipes, bearing a range of cellules on each side, often showing an initial point or radicle at the base, and an extension of the slender axis above and beyond the celluliferous portion.

From these forms with a double series of cellules, we pass to the broad foliiform stipes, which are apparently composed of four semi-elliptical parts conjoined along their straight sides, and thus present four ranges of cellules. These forms (*Phyllograptus*) are, in some species, broad and short, while others are elongate, with sub-parallel sides, as shown in the accompanying figures.

[See also plates xv and xvi.]

Fig. 22.



Phyllograptus augustifolius.

(See illustrations under generic description, and plates xv and xvi.)

Fig. 23.

Phyllograptus typus: a group of separated stipes as they lie upon the surface of the shale.

From the occurrence of a large number of these leaf-like stipes, sometimes crowded together in a small space, I have inferred that they may have grown as *Retiograptus*. (Plate xiv, fig. 9.)

Following the forms with a double series of cellules, are those of similar general form, the *Retiolites*, which are known only as simple stipes. (Plate xiv, figs. 1–5.)

In the *Retiograptus* we have simple elongate stipes; and in one form (plate xiv, fig. 9) we have the stipes united by slender basal extensions in a spreading frond, in a manner not unlike some of the graptolites proper, with the parts in bilateral arrangement.

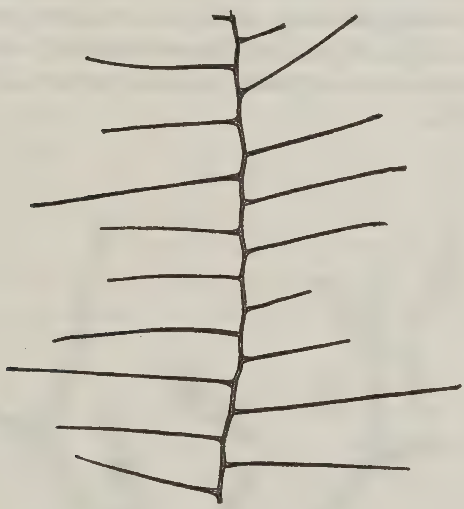
In the genus *Rastrites* of Barrande we find a departure from all of the preceding forms in the slender stipes with delicate slender tubular

cellules.* The species of this genus, so far as known, have the cellules developed on one side only of the stipes or branches; though there seems no reason why we should not have species with cellules upon the two sides of the axis.

The species for which I have proposed the name *Thamnograptus* consist of slender cylindrical stipes and branches, some of them very similar in general aspect to *Rastrites*, but the alternating branches are long and slender, and we have found no appearance of cellules on any part of the specimens known.

In the accompanying illustration the branchlets are given off alternately on the opposite sides of a stipe or rachis, and the slender solid axis can be traced from the main stipe into and along the centre of the branchlets. The analogy between these forms and the celluliferous graptolites of the preceding illustrations does not appear to be very intimate, but they occur in the same beds, and the fossil has the same texture and substance.

Fig. 24.



THAMNOGRAPTUS TYPUS.

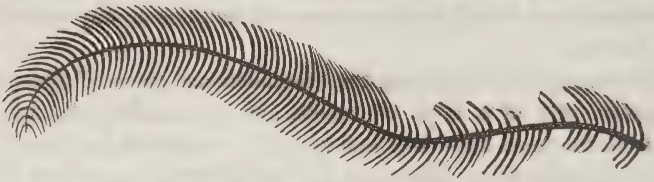
In the genus *Ptilograptus* (plate xxi) we have a somewhat analogous mode of growth, but there is always an aspect or expression of the fossil which distinguishes it from *Thamnograptus*. In one species of *Ptilograptus* moreover, cell-apertures have been detected on one side of the branches or pinnulæ.

In the *Buthograptus* we have a form bearing some analogies with the

* See illustration of *Rastrites Barrandi* under section iii, p. 26, of this introduction.

preceding, but the rachis is flexible, and is not known to be branched, while the slender alternating pinnulæ are flat and simple, as they have been observed in numerous individuals. The specimen represented is even less curved than the usual condition of this species in the slaty Trenton limestone of Wisconsin.

Fig. 25.

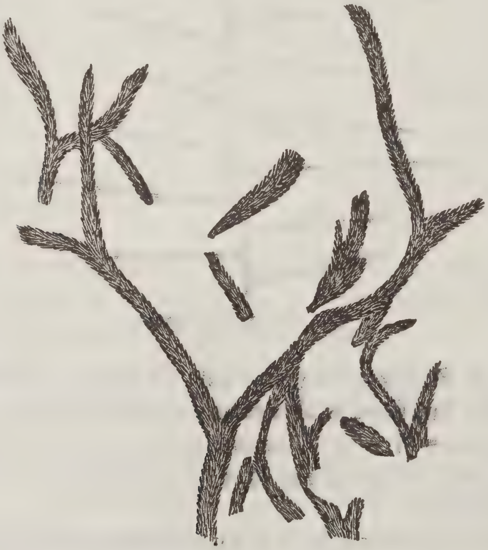


BUTHOGRAPTUS LAXUS:

enlarged.

Still more obscure, and perhaps remote in its analogies with graptolites, is the genus *Inocaulis*, consisting of flattened scabrous stems, associated with *Dictyonema* in the shale of the Niagara formation, which, from their carbonaceous substance and apparent graptolitic texture, I have referred to the Graptolitidæ.

Fig. 26.



INOCAULIS PLUMULOSA.

§ II.—THE CENTRAL OR BASAL PORTIONS OF THE GRAPTOLITE.

1. The radicle, or initial point.
2. The funicle, or non-celluliferous connecting portions of the stipe.
3. The central disc.

1. *The Radicle, or Initial Point.*—In the most simple forms, or those with two stipes, as shown in all the figures on plate i, there is a slender initial process, which I have termed the radicle. This presents a greater or less development in the different species; in some being reduced to a mere pustule, or scarcely perceptible point, while in others it attains a quarter of an inch or more in length. Although in none of the species with a single range of cellules does this part show absolute evidence of having been attached to any other substance at the maturity of the fronds, yet it is possible that in the earlier period of its growth, the body may have been temporarily attached at this point to the sea-bottom or to some object; though all the evidence is opposed to this view.

In some of the bi-celluliferous forms, and probably in all of them, there is a somewhat similar extension below the base of the celluliferous portion of the stipe, though it is usually more slender; but whether this is always the true initial point of the whole body, or whether it is only the broken point of attachment to a frond, may sometimes admit of doubt. It is conspicuous in *Phyllograptus typus*; and we observe this feature also in *Retiograptus*; but in one species of this we learn that it is only a broken process of attachment of the individual stipe, which existed as one of the members of the entire frond, the true initial point of which would be in the centre of the whole. (Pl. xiv, fig. 9.)

In all the forms of Graptolitidæ which appear to have been free, the initial point or radicle is in fact the commencement of the *solid axis*, which will be noticed farther on. In those graptolites with two simple stipes, the little radicle-like process enlarges above, and the stipes, diverging in opposite directions, are closely united at their bases, and the cellules begin almost in the axil between the two. (Plate i, figs. 1, 3, 7, 9, and 10.)

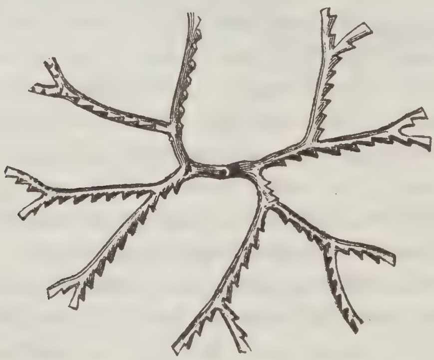
2. *The Funicle.*—In the graptolites with four stipes, the condition appears like that of two individuals of the two-stiped forms, conjoined by a straight connecting process of greater or less extent, with the radicle point in the centre, though often obscurely marked. This connecting process is *always destitute of cellules*; and this, with its divisions, I have termed the funicle.

In those forms with eight stipes the funicle is twice divided at its two extremities; and where there is a greater number of simple stipes, it is

correspondingly subdivided. Neither the central portion, nor any of its subdivisions, becomes celluliferous; and these parts are not termed stipes or branches, according to the views I have entertained. It is only beyond the last subdivisions of this part of the body, as in *G. Logani*, that the celluliferous parts, or the true stipes, commence.

In one of the proper branching forms, however, the cellules begin immediately beyond the first subdivisions of the funicle, as in the four-striped species. (Fig. 27.)

Fig. 27.



GRAPTOLITHUS MILESI.

These barren, or non-celluliferous portions of the graptolitic body, are not otherwise essentially different from other parts of the stipe. In the absence of cellules they are consequently more cylindrical, and apparently more solid, as if the test were thicker, and the common canal less developed than in the other parts of its extent.

3. *The Central Disc.*—In several of the species having four simple stipes, in one species with eight, and in another with a larger number of simple stipes proceeding from a common centre, we find their bases united by a thickened corneous expansion of the same substance as the body of the graptolite. This appears to be composed of two laminæ, which, at least in the central portions, are not conjoined, and the space is probably occupied by some softer portion of the animal body. (Plates v–ix.)

The substance of the disc sometimes extends along the margins of the stipes, producing an alation, as in *G. alatus*. (Pl. vi, fig. 9.)

This arrangement of the parts of the body seems obviously adapted to give strength and support to the bases of the stipes; but beyond this it probably serves other purposes of the animal economy. In several specimens of *G. bicornis* there is a disc or bulb at the base of the stipe, which, spreading between the two oblique curving processes, envelopes, in the compressed condition of the specimens, some of the celluliferous part

of the stipe at its base. In other specimens we have a crescent-shaped extension, as if the disc were in process of development, or perhaps of absorption. Much the larger proportion of the specimens of this species, however, are destitute of disc or bulb, and have every appearance of being complete without this appendage.

These aspects of the species are shown on plate A, figs. 13, 15, 16, and 17.

How far the bulb-like appearance at the base of some of the species of *Dendrograptus* may correspond to the disc of *G. bicornis*, I have not at this time the means of satisfactory determination.

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§ III.—THE NATURE AND PARTS OF THE STIPE PROPER.

1. The solid axis.
2. The common canal.
3. The calycles or cellules.
4. Nature and ornaments of the test.

1. *The Solid Axis.*—All the graptolites proper have been found to be provided with a slender solid axis,* while this feature has not been satisfactorily proved in regard to *Dictyonema*, and to some other forms.

In those species having a single series of cellules, this axis is upon the back of the stipe, or on the side opposite to the celluliferous margin; and in the branching forms it follows all the ramifications. In all the specimens where it has been observed, it is a slender cylindrical or flattened filiform solid body. In some extremely compressed specimens, this axis appears as a slender elevated ridge along the back of the stipe; and where the substance of the body has been removed, it leaves a narrow groove along the margin of the impression.

In the examination of large numbers of specimens of the monoprionidian species, we have never found the axis prolonged beyond, or denuded of, the cellules; as shown in *G. colonus*, by Barrande, in his Graptolites of Bohemia. (Plate ii, fig. 5, of that memoir.)

In all the specimens where the extremities of the stipes are entire, as represented in plates i, ii, and iii of this memoir, there is never any extension of the axis beyond the last partially developed cellule; and the number of specimens in this condition is considerable.

In the graptolites with two series of cellules, the solid axis is very

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* In those species with a single series of cellules, M. Barrande has ascertained that this axis is solid and cylindrical, its diameter not exceeding ¼ millimetre, and its structure apparently fibrous. (*Graptolites de Bôhème*, page 4.)

frequently seen extending beyond the celluliferous portion of the stipe at its outer extremity; while the radicle appears like the continuation of the same below the base. The axis thus appears to be the foundation on which the other parts are erected. In those specimens, however, which present so great an extension of the solid axis beyond the stipe, the cellules may have been removed by subsequent causes.

I am able to corroborate to some extent the observations of M. Barrande in regard to the apparent double character of this axis. In some extremely compressed specimens it is marked by a longitudinal groove or line of division;* while in others, a double impression has been left by the removal of the substance.

In some specimens, particularly the younger ones, the solid axis has been seen extending beyond the base of the stipe, as a duplicate process, exhibiting a character as of a double radicle. In some solid specimens of one species, where the tube had been filled with calcareous mud, I am able to detect only a single round point; and a longitudinal section of the same species presents a slender filiform axis. It may be, however, that the parts are so minute and so closely united, as to render them undistinguishable.

In another species, with two rows of cellules, and in which the latter are of very different form from the preceding, the solid axis is a thin flat apparently double plate, extending across the entire transverse diameter of the tube, which is more than two-thirds as great as its longer diameter. The place of the axis is marked by a longitudinal groove on each side, not in a direct line, but slightly undulating to correspond with the cellules. M. Barrande conceives that the joining of the two plates of this axis may leave a very flat intermediate tube; and in our specimen, there is apparently an extremely narrow space between the two. He farther supposes that each of these plates, composing the double axis, is separable, by decomposition, into two laminæ, as illustrated in plate iii, fig. 3, of the work already cited.

The entire appearance of the species (plate A, fig. 10) is that of two monoprionidian stipes joined together at the back, the line of junction being indicated by the groove.

In one species of *Retiolites* there is a strong excentric or sub-exterior axis, which is nearly direct; and in the same individual there is another undulating axis, to which the cell-divisions of one side are attached. In the *Retiolites* of the Quebec group, one side of the stipe shows a very distinct axis, while upon the other side it is very obscure.

In *Retiograptus* we have a very distinct central axis projecting below

* The aspect presented by the axis, when marked by a longitudinal groove, is precisely that which a hollow cylindrical body would have if extremely compressed.

the celluliferous portion of the stipe, and, in one species, uniting in a funicle, and forming part of a compound form. In another species, the simple stipes present similar features, showing at one extremity the duplicate character of the axis.

In *Phyllograptus*, the central axis is apparently composed of four slender flat laminæ; but we have had no means of examining this part of the body in a satisfactory manner.

2. *The Common Canal.*—In all graptolites with a single series of cellules, there is, between the bases of these cellules proper and the solid axis on the back of the stipe, a continuous sub-cylindrical space or canal, which has been occupied by the body of the polyp, from which the buds, with their calycles forming the cellules, take their origin, and are thrown off at regular intervals.

All the specimens which I have examined confirm this view; and in some of the species where the extremities are apparently entire, we observe the incipient development of the young cell from the common body. In those specimens filled or partially filled with the substance of the surrounding rock, this canal is easily distinguished; while in compressed specimens there is always a flattened space between the bases of the cell-partitions and the solid axis.

In those graptolites with two ranges of cellules, we have apparently a duplication of those with the single series, the two solid axes being joined together, leaving a common canal or body on each side at the base of each series of cellules. If however the common body were thus divided, it would be by the solid axis becoming a flattened plate. This appears to be true of some species (as for example, plate A, fig. 10), while in others there is only a simple filiform axis visible. In this case, of course, there is not an entire division in the common canal after the manner of the other species. This will appear farther on, under the illustrations of the structure of these bodies.

In *Retiolites*, the common body occupies the central portion of the stipe, giving origin to a series of buds on each side, while it is not divided by a central axis.

In some species the common body seems likewise to have more extensive functions; for in such forms as *G. divergens* and *G. gracilis*, there is a long slender rachis, or tubular body, destitute of cellules except at its two extremities, and apparently consisting of a solid axis and a common canal, from which originate, at regular intervals, simple small stipes with solid axis, common canal, and cellules.

This appears to be one step farther in our knowledge of the origin or mode of development; but it shows that a stipe or main axis may produce in one part celluliferous stipes, and in its extremities develop only cellules, as we see in the continuation of the main axis of *G. gracilis* and

G. divergens, where the continuation of this common rachis is marked by marginal cellules of the same character as those of the lateral stipes.

The common body therefore appears to perform the double function of developing the buds which elongate into stipes with cellules, and also of simple cellules; or we may consider the celluliferous extremity of the rachis, or main axis, as the termination of the reproductive process, or as analogous to one of the lateral celluliferous stipes. In the Sertularians we have something analogous to this mode of development. Some of the species have cellules along the common or main trunk, and produce at intervals branches or branchlets in place of cellules; others have a common body, or main stem, entirely destitute of cellules, but producing branches on each side (opposite or alternate, as the case may be), which branches produce cellules only.

So long as this rachis gives off only celluliferous stipes, it is analogous to those parts of the simple graptolites which I have termed the funicle, having within itself the sources of this development of the several parts. The mode of development differs from that of the branching forms, inasmuch as the branches proper arise from a division of a cell-bearing stipe or branch, and of course a division of the solid axis and common body.

In *Retiograptus*, some specimens show the cell-divisions reaching nearly to the axis, leaving room on each side for a narrow common body or canal; while in a species from the Utica slate, which presents one side of an entire frond, the cell-divisions of the exterior side all reach to the axis, leaving the common body on the inner or upper side. In a species from Norman's Kill, near Albany, there are three parallel ranges of reticulations, with apparently two filiform solid axes, forming the divisions between the three meshes. This structure probably occupies one side of the stipe, while the common body may occupy the other side.

In *Phyllograptus*, the cell-partitions reach very far towards the centre, and the space left for the common canal is very small. We infer from the better-preserved specimens that there is a slender common canal at the base of each range of cellules. These several canals may or may not communicate with each other.

3. *The Calycles or Cellules: their form and mode of development.*—Since a large proportion of the specimens of graptolites which come under our observation for the purposes of study or otherwise, are fragmentary, it becomes of much importance to know the general characters of form and mode of development of the cellules.

In the preceding section it has been shown that the cellules, or the inhabitants of these cellules, are not independent, but all have their origin in a common body, which fills the longitudinal canal, and that they remain in constant connection with the same throughout their existence.

The calycle or cellule is formed by budding from one side of the com-

mon body, not unlike many of the Sertularians, except that the cellules are generally close together at their origin.* They are usually more or less oblique to the direction of the axis, as is clearly indicated by the cell-partitions; and the degree of obliquity often indicates specific distinction. The cellules are for the most part contiguous at their origin, and they sometimes remain in contact throughout their entire length; but in the greater number of species there is a small portion of each one free on one side towards the aperture. This character is shown in numerous examples. (Plates i, ii, and iii.)

In some forms the cellules are contiguous in their lower portions, while the entire upper or outer part becomes free, as seen in *G. Clintonensis* (plate B, figs. 1, 2, and 3); while in one of the bi-celluliferous species from Iowa, the cellules are distant from each other at their origin, and the upper extremity of one scarcely reaches to the base of the next in advance (plate A, fig. 10); and they are therefore not properly in contact in any part of their length. The same is more emphatically true of *Rastrites*, (fig. 27), where there is a large interval between the bases of the cellules, which are often nearly rectangular to the axis.

Although we regard the cellule as limited by the cell-partitions, yet in well-preserved specimens there is sometimes a swelling of the test of the common body below the cellule, indicating an enlargement of the parts at the bases of the buds. In one species there is an evident undulation of the axis, corresponding to this enlargement of the parts in the common body. (Figs. 10 and 11, plate A.)

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* The mode of budding and the form and arrangement of the cellules in the Sertularians are shown in the accompanying figures of two species of *Sertularia* (figs. 1 and 2) from our own coast. Fig. 3, with a range of cellules on one side only, is a *Plumularia*.

Fig. 1.

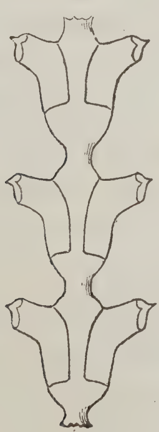


Fig. 3.

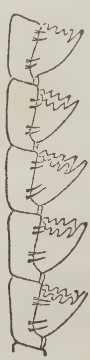
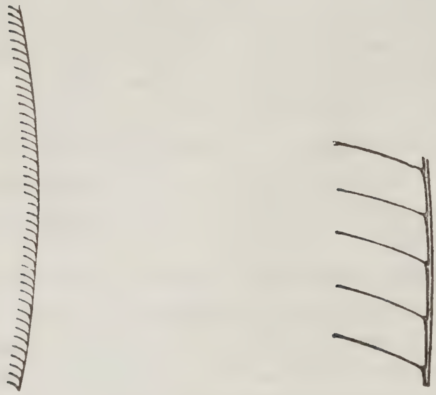


Fig. 2.

Fig. 28.



Rastrites Barrandi:

natural size, with a portion enlarged. The cellules consist of long slender tubes.

In the diprionidian species, the cellules on the two sides of the stipe are alternating, so that the bases or the apertures are opposite the space between two others. This is more especially shown in the enlarged figures 10 and 12, plate A.

In much the larger proportion of species, the body of the graptolite and the cellules are so extremely compressed, that they appear only as serratures along the margin, with distinct impressed lines marking the cell-divisions. The exterior margin of these serratures indicates in an approximate degree the outline of the aperture; and the frequently occurring mucronate extension at the extremity of the cellule is produced by the continuation of the cell-partition, or sometimes by an outgrowth from the margin of the stipe above or below the aperture.

Were the cellules isolated, their prevailing form would be that of an elliptical tube or sac, the length of which is greater than either of the two diameters. When they are in juxtaposition, however, the contiguous sides are flattened, while the lateral or external surfaces are usually more or less curved, particularly near the aperture. In a larger proportion of the species, the calycle becomes slightly expanded towards the aperture; but in a few examples there is a distinct contraction above the middle, and the aperture is smaller than the base. Generally, however, the smaller diameter is just at the junction with the common body, or at the junction of the cell-walls with the walls of the common canal.

In a single diprionidian species, where the specimens are not distorted by pressure, a longitudinal section of the stipe in the direction of its greatest diameter (plate A, fig. 12), shows the cellules scarcely narrowed at their origin with the common body; while in a lateral view of the specimen,

the base of the cellule is seen to be much wider than the orifice. (Plate A, fig. 10.)

In many of the species a transverse section of the cellule near the base is quadrangular, becoming more rounded towards the aperture; and when the upper part of the cellule is free, the aperture is round or elliptical, and in some specimens the calycle is elliptical or cylindrical throughout its entire length. We have examples of the quadrangular cellules in *G. extensus* (plate ii, fig. 16) and *G. octobrachiatus* (plate vii, figs. 5 and 7); as well as in two species of *Phyllograptus* (plates xv and xvi). Where the cellules are more nearly isolated, they approach more and more to the cylindrical form. As examples of cellules contracted towards the aperture, we have *Graptolithus priodon*, Barrande, and *G. Clintonensis*, Hall. (Plate B, figs. 1, 2, and 3.)

M. Barrande has remarked that from the circumstance of the partial or complete isolation of the successive alveoles of the same series, we may easily conceive that the walls of contact in contiguous cellules should be double. This fact he has ascertained from decomposing specimens of *G. priodon;* and we have the same evidence in some of our species. In the cellules of the ordinary mode of development, each one is an independant part of the organization, and is provided with its individual body and cell-walls, as if each cellule were isolated. Whenever two of these are in contact, the cell-walls coalesce as far as the contact continues; but when becoming free, the cellule assumes its normal condition. In some specimens of *Phyllograptus* we find this evidence of double walls in the cell-partitions.

In *G. putillus*, illustrated on plate A, figs. 10, 11, and 12, the cell-walls, although contiguous to and adjoining the walls of the body (and not free), do not coalesce, but are readily separable without fracturing their substance.

There are cellules however where the production of the calycle by budding from the common body is not so obvious. These forms are like *G. bicornis* and *G. antennarius*, where the orifice is a simple transversely-oval aperture in the side of the stipe. In the flattened specimen it appears like a rectangular or slightly oblique, semi-oval notch in the margin. Its true form is perceived only when the cavities of the polyp have been filled with mineral matter, or when the stipes are flattened vertically against the apertures: they then give the form which has been described as *G. scalaris*. This form of cellules is shown on plate A, figs. 1 and 2, which are enlarged from a specimen retaining nearly its original proportions. Just within the limits of the cellules, and extending the entire length of the stipe, there is a longitudinal depressed line; and along this line, and running thence almost rectangularly to the outer limits of the stipe just above the aperture, the cell-partitions join the exterior test, and project in an extended border or flange.

In specimens stripped of the test, where the interior has been filled with stony matter, the cell-partitions present the appearance shown in fig. 3, plate A; while there is a large central space apparently occupied by the common body, but without the appearance of a central axis on the exterior surface. When the surface is ground down to a plane intermediate between the exterior and the centre, it presents the aspect of fig. 4; and when the cutting is carried to the centre, it gives the characters of fig. 5, the cell-divisions apparently reaching to the axis.

The general form of this stipe in section (fig. 6) approaches that of *Retiolites*, as shown by Barrande and Geinitz; and in the arrangement of the common body and axis there is a departure from the typical diprionidian forms of *Graptolithus*. In this transverse section we have a somewhat concavo-convex form, which is narrower on the concave side. There is a central or sub-central point indicating the filiform solid axis; and on each side of this are the divisional cell-walls, which produce a slight contraction of the exterior walls of the stipe at the inner limit of their attachment. Another section, fig. 7, shows the same features, together with the remains of two other cell-divisions, neither of which reach to the exterior walls of the graptolite; and the one on the right hand shows the narrow extremity just before joining the axis.

These sections, together with numerous other longitudinal, transverse and oblique sections, compel us to conclude that this graptolite possesses a filiform central or sub-central apparently solid axis; and that the cell-partitions originate from, or are joined to this axis. These cell-partitions appear to consist of triangular plates, which have an unequally arching or convex upper surface, and a concave lower surface. This form of cell-partitions would leave the alveoles to communicate at their bases with the common body on each side.*

In some forms having cellules of this character, as in *G. bicornis* proper, there is, in the flattened stipes, an external ridge, as if indicating the junction of the axis with the external walls. But in examples where this axis extends beyond the celluliferous portion of the stipe, it is compressed, having the aspect of a flattened cylindrical filiform body. It has no appearance of having been flat, or laterally extended within the body of the stipe.

In the ordinary forms of graptolites the orifice of communication between the cellules and the common body is usually round, oval, or quadrangular;

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* The cell-partitions in this form of graptolites are represented as they appear to exist in the solid specimens examined, on plate A, fig. 9; where, curving gently downwards on their exterior margins from the upper edge of the orifice, they turn more abruptly towards the axis, while the central portion extends obliquely to the axis, leaving a broad arch above, which gradually becomes angular as it approaches the axis.

and this appears to be true of all the species with a single range of cellules, and also of the ordinary forms of those with two ranges of cellules, where the common body is divided by a longitudinal axis.

In *Retiolites*, where there is no well-marked division limiting the common body, the union of the cellules with it is not so well defined; nor does there appear to be in these forms a continuous cell-partition: the cellules open in a quadrangular aperture, which is a little oblique to the transverse diameter.

In those graptolites with the simple transversely-oval orifices in the test, as *G. bicornis*, the arrangement of the common body and the communication of the cellules differ from all the other forms. There is an apparent double communication with the common body, giving not only the usual bilateral arrangement of the parts generally, but a bilateral arrangement of the parts in the individual alveoles.

The external orifice of the cellule in graptolites is extremely variable in form, and in its relative direction to the body of the cellule, and to that of the general axis. In a large proportion of the species, the aperture is oblique to the axis of the cellule, a little expanded, and thickened at the margin. The lower or posterior edge is often prolonged into a mucronate point or expansion. This feature, combined with the various degrees of curvature at or near the aperture, produces a great diversity of external expression in the orifice.

In *G. nitidus*, plate i, and in *G. similis* and *G. extensus*, plate ii, the plane of the orifice is nearly rectangular to the axis of the cellule; while in *G. bifidus*, *G. pennatulus*, and others, the margin is produced into a strong mucronate extension. In *G. octobrachiatus* the line of the cell-margin makes an angle of more than 90° with the axis of the cellule.

In mature individuals of *G. Clintonensis* the upper part of the cellule is re-curved, and the orifice opens downward nearly at right angles to the general axis, having a slight spreading and thickening of the border. In less mature individuals the orifice is apparently angular, and opens upward, while the plane of the aperture makes less than a right angle with the direction of the general axis. It would appear that in the progress of growth the cell-walls are continued, gradually contracting above, and, after becoming free from the adjacent cellule, form a slender, gradually curving tube, which in mature individuals has its orifice directed backward.

In *Dendrograptus*, the form of the orifice and outline of the aperture present variations similar to those of the simple uniserrate graptolites; but some species show modifications in the form of the cellule which do not accord with the more simple forms. In *Dictyonema*, the cellules are not fully known; the orifices are marked by a prominent mucronate extension, and apparently simulate the more common forms of graptolites. (Fig. 5, plate B.)

In the bi-celluliferous species the compressed specimens present the plane of the orifice, sometimes rectangular to the general axis, sometimes with the outer margin a little advanced, making an acute angle with the axis of the cellule, while sometimes the plane of the margin of the aperture is rectangular to the axis of the cellule, or rarely makes with it an obtuse angle. The cellules of *Retiograptus*, which have not yet afforded means of satisfactory examination, apparently have their orifices nearly rectangular to the general axis of the stipe.

In one of the forms of the bi-celluliferous graptolites the cellules are sub-elliptical tubes, with an orifice of corresponding form, without extension beyond a slight thickening or callosity at the margin of the orifice. The plane of the cell-aperture in this one makes an obtuse angle with the direction of the general axis.

In forms like *G. bicornis* the external orifice is transversely oval, with or without a projection and thickening of the test from the cell-partition above the orifice, or extension of the test.

4. *Ornaments of the Test.*—The compressed condition in which the graptolites usually occur is unfavorable to the preservation of any minute surface-markings, or ornaments of the test.

In many of the species, fine striæ, parallel to the margins of the cell-apertures, are perceptible, and in the larger number of species this marking is all that is preserved. There is sometimes a granular appearance of the surface, but I have not been able to satisfy myself that this is the actual surface-texture ; it may be a condition induced by mineralization. In a few examples there is a row of minute pustules at the base of, and corresponding to the cellules.

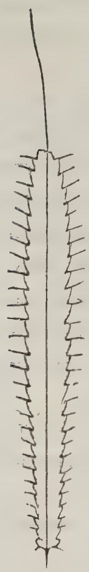
The stems and branches of *Dendrograptus*, *Callograptus*, and *Dictyonema* are irregularly striated. In typical species of *Retiolites* the test is finely reticulate ; while in the species from the Quebec group, this texture, if existing, is so fine as not to be readily resolved by an ordinary lens. The surface however has not the appearance of entire smoothness, as in most of the ordinary graptolites.

The chief ornaments of these bodies are the mucronate extensions of the test, usually from the lower margins of the cellules, but sometimes from the upper margins. In ordinary forms of the species, with single, and with double ranges of cellules, the mucronate or setiform extensions are usually from the lower extremity of the cell-aperture, as illustrated in fig. 29.

In all those forms of which *G. bicornis* may be regarded as the type, these processes, when existing, are extensions of the test above the aperture, so far as observed (pl. A, figs. 1, 8, 9) ; or as in species of the character of fig. 20, plate A.

In some species, as *G. quadrimucronatus* (plate xiii), there is a

Fig. 29.



Graptolithus Whitfieldi:

twice enlarged.

mucronate point extending from each angle of the cellule ; as also in *G. testis* of Barrande ; except that in the Canadian species these appendages are more rigid.

In *Phyllograptus typus* and *P. ilicifolius*, these processes are apparently the extension of the angles of the cell-partition.

The cellules of *Dendrograptus*, *Callograptus*, and *Dictyonema* sometimes show mucronate extensions from their outer margins. In *Retiolites* the cellules sometimes terminate in a plain margin, and in one species the divisions are extended in short strong mucronate points. (Plate B, figs. 5 and 21, and plate xviii, fig. 6.)

All the species of *Retiograptus* have the margins of the stipes garnished with slender mucronate points, corresponding to the cellules, and extending almost rectangularly to the axis. (Plate xiv, figs. 6–9.)

These ornaments are not always uniformly developed in the same species, or even in the same individual. In the larger proportion of specimens of *G. ramosus*, the margins of the cellules are apparently plain; but in the cellules of the simple part of the stipe we sometimes find a rigid mucronate point, prolonged from the upper margin or limit of the cell-aperture. (Plate A, fig. 20.) In *G. sextans*, the mucronate point is half-way between the two cell-apertures.

In specimens of *G. sextans*, and in some allied forms from the Hudson

River formation at Marsouin, Canada, the stipes and cellules are less fully developed than in those of the same species from Norman's Kill near Albany, while the mucronate extensions from the cell-apertures are more conspicuous.

Besides these ornaments, there is on each side of the radicle or initial point at the base of most of the diprionidian species of graptolites, a small process, varying in length, and usually directed downwards. These processes are usually short, but often considerably extended; in some species they are very slender, while in others they are strong and rigid. In *G. pristis* they are frequently seen as short slender processes; while in *G. bicornis* they are rigid, strong, and slightly curving. In *G. antennarius*, a congener of the latter, they are long and slender setiform appendages. In one species of *Retiograptus* they are slender setiform processes, directed downwards.

In no species of *Phyllograptus* have such appendages been observed; nor have they been seen at the bases of the stipes of *Retiolites*.

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§ IV.—MODE OF REPRODUCTION AND DEVELOPMENT IN THE GRAPTOLITIDÆ.

As already remarked, the graptolites proper are now generally referred by authors to the Radiata; while some forms which I include in the family have been heretofore regarded as reticulate bryozoans, or as gorgonians. The nearest analogues in the recent fauna appear to be among the group Pennatulidæ, or in the Sertularidæ; but in all these there is no absolute identity in the mode of development or character of cellules, so far as my observation has extended.

In nearly all the true bryozoan forms among fossils, we have the means of tracing the relations and analogies, both in manner of growth and reproduction, throughout all the successive geological periods, and in the present fauna. It becomes therefore more difficult to discover such analogies for the Graptolitidæ, since the graptolites proper disappear from existence in the Silurian period; and the latest form of Graptolitidæ (*Dictyonema*) is not found, so far as now known to me, in American strata, at a later period than the Hamilton formation or Middle Devonian. From this cause, the mode of growth and development are not so readily understood as in those families which can be traced throughout the geological series, and still find their analogues in the present seas.

In 1858, I laid before the American Association for the Advancement of Science a notice, with some illustrations of graptolite stipes, bearing what I then regarded, and do still regard, as the reproductive cells or ovarian vesicles. These cells first appear as small ovate buds upon the

margins, projecting but little beyond the regular cellules, and, becoming enlarged, form elongated sacs with swollen extremities, which are finally dehiscent; and then, as I suppose, discharging the ovules or germs, are gradually absorbed or dissipated.

Although these sacs are distinctly defined, they have scarcely any apparent substance, except along the lateral margins, which are limited by a filiform extension resembling the solid axis of a graptolite. There are likewise numerous fibres of this kind traversing the sacs; and these sometimes remain attached to the original stipe after the other parts are separated. In one example, we have conclusive evidence that they are connected with the solid axis of the parent stipe. The gradations of development in these sacs may be studied in the figures 6–9, plate B.

In the specimen fig. 10 of the same plate the ordinary cellules are removed, and the fibres are still seen joined to the axis, showing the origin of the reproductive sacs. In most specimens bearing these sacs, the cellules of the stipe are so obscure that the species cannot be determined; but in fig. 9 we find them attached to a well-marked stipe of *G. Whitfieldi.*

This mode of reproduction in the graptolites shows much analogy with the Hydroidea, and would indicate the sertularians as their nearest analogues.*

Upon the surfaces of the slate where these bodies occur, there are numerous graptolitic germs, or young graptolites of extremely minute proportions, ranging from those where the first indications of their form can be discovered, through successive stages of development till they have assumed the determinate characters of the species.

In several examples, these minute germs have been detected near to and in contact with the reproductive sac; and in one case, there is but a hair's-breadth between one of the fibres of the sac and one of the oblique processes at the base of the germ. It cannot be said that we have detected the germ actually within the sac; but the numerous young individuals lying near them, and upon the surfaces of the same laminæ, offer very good arguments for supposing that they have been thus derived.

The earliest defined form which we observe in the young graptolites

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* In the recent *Sertularia* and *Campanularia* we find ovarian vesicles, in which a number of ovules may be enclosed in a common envelope. These vesicles are developed along the side of a stipe or branch, and the ovules are often arranged along a central axis, each one communicating with the common axis of the zoophyte. [Jas. J. Lister, *Philosophical Transactions*, 1834, pp. 365–388, pl. ix. Cited also by Dana, "*Structure and Classification of Zoophytes*."]

Prof. McCoy has stated (*British Palæozoic Fossils*, p. 4) that he has found near the base of the cellules of graptolites, a transverse partition or diaphragm, similar to what may be observed in some sertularians, and which he regards as proving similar relations; but I have not discovered in any American specimens evidence of such cell-diaphragms.

consists of the initial point or radicle; a diverging process of similar character on each side, but not quite opposite; a longitudinal axis of greater or less extent; and a sac-like covering, or thin pellicle of graptolitic test, which has scarcely assumed the form of cellules, but which is most extended in the direction of the common body along the solid axis. This little sac contains the germ of the zoophyte, which, extending itself as the common body in its canal along the axis, gives origin to the budding which develops the successive cellules and the gradual building up of the stipe.

The earliest condition of development is illustrated in fig. 12 of plate B.* At a farther stage of development we have the form better defined, as in fig. 13, where the germ has assumed the general aspect of *G. pristis*, the slender lateral processes being rectangular to the axis.

On the left hand of fig. 8, and at the third reproductive sac below the top, there are two germs visible, close to the sac, where the connection between one of these and the fibre is nearly complete. The same is shown in the enlarged fig. 11.

In figure 14 we have the germ of another form, which is unequally developed on the two sides. Figure 15 (represented of the natural size) appears to be of the same species, having reached a more definite form. Figure 16 is an oval disc, of which several more or less defined specimens have been found among the young graptolites, but I have not been able to trace it to any known mature form.

The specimens figs. 17 and 18 appear to be the young of *G. bicornis*, or of a similar form. In one the body is narrow, without marks of cellules, and the solid axis is not extended above the common body, being probably broken off. In the other there is a greater expansion of the common body, but no cellules are visible, and the central portion of the substance is more dense, while towards the margin it is extremely thin; the solid axis is extended beyond the stipe, and the lateral oblique processes are quite perfect. This germ, with its axis and common body, had not begun to develop the cell-apertures on its margins, which may be seen at a later period.

In nearly all the young graptolites there is an extension of the common body along the axis above the incipient cellules. This is observed in the figures referred to and in the young of *G. ramosus*, shown six times enlarged on plate A, fig. 21.

Although I have found none of the monoprionidian forms with reproductive sacs attached, I have nevertheless observed what appear to be the young of some of these species, having an aspect similar to the others,

* All the specimens of germs or young graptolites are six times enlarged, except figs. 11 and 17.

except in carrying the development upon one side only of the solid axis. An illustration of one of these forms is given in fig. 19, plate B, showing the base irregularly divided. These forms cannot be referred to any known mature species.

This mode of development, illustrated in numerous specimens, can be readily understood in the simple stipes whether of the monoprionidian or diprionidian character. Admitting that the examples given furnish evidence of the mode of reproduction of the diprionidian forms, or those of the sub-genus *Diplograptus*, where we have a range of cellules on each side of a solid axis, it is easy to perceive how the germ of an analogous form may develop from its initial point two series of cellules upon a stipe, where the parts diverge in opposite directions from the common origin or initial point. One step farther in this direction will give us the four-stiped forms, where the germ of the common body, with its additional elements of subdivision, produces the quadripartite frond; and so onwards, until we have the numerously-branched fronds and the branching stipes.

In all these, the germ in its incipient development will differ very little. It may consist of the radicle or initial point, with the solid axis, and the common body, separated into two, four, eight, or an indefinite number of divisions, each one bearing its solid axis and common canal. These subdivisions sometimes all take place near the origin, which is always central; and the divisions continue simple throughout, or do not bifurcate after they commence to develop cellules.

In others the stipes are again divided, and this subdivision is only limited by the extent of the frond. In all these fronds the parts are always arranged symmetrically or bilaterally on the two sides of the initial point; as has been illustrated in the preceding pages.

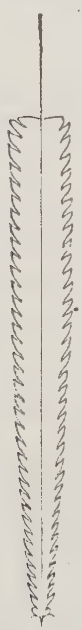
Throughout all the monoprionidian forms, or those illustrated on the first twelve plates of this memoir, we have only modifications of the simplest form of development shown in the species of plates i and ii. Where the divisions at the base become more numerous, (and indeed in the four-striped species,) we find a thick corneous test, of the same substance as the other parts of the graptolite, uniting the bases of the stipes and continuing along their margins. This plate has a greater or less development, not always corresponding to the size or extent of the stipes. It is sometimes absent, apparently from accident, and some of the four-stiped species are not known to possess it; while it has never been observed in any of the species where the stipes are properly branched, or divided in the celluliferous parts of their length.

The interior of this corneous disc, previously described as apparently composed of two plates of the test, has probably been occupied by some softer substance, which may have been an extension of the common body, or have had in some degree the character of the common body of the stipe.

The development of the diprionidian forms, as deduced from the young graptolites which we find associated with the reproductive cell-bearing stipes, would show that these forms of graptolites exist as single and simple independent stipes from the commencement of their growth. Nevertheless I conceive that both *Retiolites* and *Retiograptus* may have existed in compound fronds, having their origin from a central point not unlike in the commencement to *Graptolithus Logani*, but without the central disc. These fronds were probably concavo-convex, as were the individual stipes. The solid axis, instead of being central, is placed externally along the centre of the convex or outer side; and the cell-divisions on that side reach to and join it; while on the upper or concave side the cell-divisions do not reach the centre, leaving a space for the common body, which has been shown by Barrande and Geinitz to produce a central longitudinal prominence.

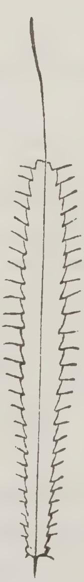
In these forms the mode of development has been similar to that already explained, the modification being chiefly in the external position of the axis and the joining of cell-divisions with the axis on one side; leaving the common body in a somewhat triangular form, from which the alveoles are developed on either side.

Fig. 30.



Graptolithus pristis: enlarged.

Fig 31.



Graptolithus Whitfieldi: enlarged.

Whether the *Phyllograptus* existed as simple stipes with four ranges of cellules, or in a compound arrangement as in *Retiograptus*, the mode of development has been similar: either the germ with its initial point developed a single stipe with four ranges of cellules, or the same elements first subdivided, and each division gave origin to its stipe through the common body.

In regard to the development of the cellules in the different parts of the graptolite, we observe, as a uniform feature, their lesser development towards the base of the stipe. In all the monoprionidian forms this character is particularly observable; and in a few species the earlier cellules are raised in a scarcely perceptible elevation above the general surface of the common envelope. Indeed in a few instances it is impossible to ascertain satisfactorily whether these earlier prominences are expanded into open cellules. As the stipe is extended, they become gradually more and more prominent, until towards the middle, or oftener perhaps nearer the distal extremity, their greatest degree of development is reached. In some species this takes place near the base, and in the more elongated stipes there is no sensible increase throughout a great part of their length, and the two margins of the stipe are essentially parallel. Towards the distal extremity there is a gradual, or often a more abrupt, diminution in the size of the cellules, and a few of the last ones are much smaller, until the terminal cellule is sometimes seen in a partially developed condition between the common body and the partition of the preceding cellule.

The same condition of development in the cellules is true of the diprionidian forms, as is shown in some degree in *G. pristiniformis*, plate xiii, but more especially in the accompanying figures of *G. pristis* and *G. Whitfieldi*, the last of which shows the higher cellules diminished, so as to contract the width of the stipe above (figs. 30 and 31, p. 36).

In *Retiolites* and *Retiograptus*, the full development of the cellules takes place below the middle of the length of the stipe, while they are less developed towards either extremity. In some species of *Retiolites*, including one from the Clinton formation, the cellules acquire their greatest development near the base, and the margins are essentially parallel for the greater part of their length.

In *Phyllograptus*, the lesser development of the cellules at the base of the stipe is a marked feature. They increase rapidly towards the middle; and their greatest development is sometimes above and sometimes below the middle, but in all cases becomes rapidly less towards the apex.

In *Dendrograptus*, where we have a stout stem without cellules, the branches usually begin at some distance above the base: and in their lower part they have scarcely the appearance of being celluliferous; in the middle of their extent the cellules become more distinct, and so far as can be observed they are less developed towards the extremities.

§ V.—MODE OF EXISTENCE.

The numerous individuals of entire or nearly entire fronds illustrated in this memoir, as well as large numbers of others examined, serve to give a pretty clear idea of the general form of the true Graptolites, as well as of their congeners of the same family. Notwithstanding the presence of the radicle or initial point observable in so many species, it does not afford evidence of attachment to the sea-bottom or to some other substance, at least in the mature condition. In all the monoprionidian forms, however much or little extended the radicle may be, it is always smooth, and tapering to a point. In many of these, and more especially in those with a central disc, this radicle is reduced to a minute protuberance, and is often scarcely or not at all perceptible.

The same is essentially true of the greater number of diprionidian forms examined. In these the solid axis is sometimes extended beyond the base of the stipe, and terminated as if broken off abruptly; while there is often a slender oblique process on each side of the base.

In *Retiograptus* and *Phyllograptus* there is not the same evidence of completeness at the base of the radicle. The lower termination, when it can be fully examined, is broken, as if there had been a further continuation of this part, though it exhibits no enlargement. I have inferred that all these, like the example of *Retiograptus eucharis* (fig. 9, pl. xiv), have constituted parts of a similar compound body, and are but the separated stipes of the frond. If this be true, their mode of existence is not unlike the other species with compound fronds and a central disc.

In *G. bicornis* the extension of the solid axis below the base of the stipe is not always preserved; but when it is entire, we find two strong, diverging and slightly curving processes or spines from the base, having smooth terminations. Sometimes a disc or bulb, of the same substance as the stipe, extends between these spines, and in the compressed condition envelopes a few of the lower cellules, as shown in fig. 17, plate A. Some of the phases presented by the basal extremities of this species are shown in figs. 13, 15, 16, and 17 of the same plate.

The expansion at the base of this species has the same general appearance as the central disc of *G. Logani*, *G. Headi*, and others; showing that this sort of development of the substance is not alone characteristic of those forms having several stipes united at the base. In other examples this basal expansion is contracted in such a manner as to give a crescent-form to the lower extremity; but in all these gradations, the margins of this part are entire and unbroken.

We have seen that the youngest forms of the diprionidian graptolites, those which we may suppose had but recently escaped from the reproduc-

tive sac, are furnished with the minute radicle-like appendage or extension of the solid axis, as well as the oblique lateral processes like tentacula; and the condition of these parts does not seem to have been essentially changed during any subsequent period of their growth. While the extension of this slender solid axis does not seem of sufficient strength to have formed the base of attachment to the sea-bottom, it may have been sufficient to maintain connection with other parts of a compound frond.

For all those species with a single range of cellules, as well as for some with a double range, including *Retiolites*, *Retiograptus*, and *Phyllograptus*, I conceive that we have already shown a similar plan of development and a uniform mode of existence; and we are constrained to believe that all these forms, in their mature condition, were free floating bodies in the Silurian seas.

In regard to another group including *Dendrograptus*, *Callograptus*, and *Dictyonema*, as well as one or two other forms, we have some evidence indicative of a different mode of existence. The stems of *Dendrograptus* are enlarged towards their base, and sometimes present a sudden expansion or bulb, which I have inferred may be the base or root, once attached to another substance or imbedded in the mud. The general form of the species conduces to the belief that they were fixed to the sea-bottom, though possibly this basal expansion may have resembled that of *Graptolithus bicornis*. In most of the species described, the lower extremity is imperfect, and its termination unknown.

In those which I have termed *Callograptus*, the bases of the fronds are imperfect, but indicate, according to analogy, a radicle or point of attachment like *Dendrograptus*. In the more nearly entire forms of *Dictyonema* known, we have not been able to observe the base; but from their similarity in form and mode of growth to *Fenestella* and *Retepora*, we have inferred their attachment either to the sea-bottom or to foreign bodies.

Nearly all these forms occur in rocks where there are few of the larger fossils of any kind except the graptolites; so that there is little chance of finding their bases attached to shells and corals, as we do those of the bryozoans, even if they had thus existed. The *Dictyonemæ* of the Niagara, Upper Helderberg, and Hamilton groups do occur in strata which contain large numbers of other fossils; but we have no evidence of their having been attached. It is only from their general form therefore, and from their analogy with other bodies, that we infer that these genera may have been attached to the sea-bottom or to some objects during their growth.

We admit therefore that the family of Graptolitidæ, as now extended, may include both free and fixed forms.

§ VI.—GENERAL CHARACTERS OF THE FAMILY OF GRAPTOLITIDÆ; WITH REFERENCE TO THE DISTINCTIVE FEATURES OF THE GENERA, AS KNOWN IN THE GEOLOGICAL FORMATIONS OF CANADA AND THE UNITED STATES.

In the first section of this memoir, I have remarked upon the nature and general form of the graptolites proper, and the allied genera which I regard as belonging to the same family. The large accession to the number of species, and the great variety of new forms added to those formerly known, require an extension of the characters heretofore given.

The numerous graptolites described by Nilsson, Hisinger, Bronn, Murchison, Eichwald, Portlock, Geinitz, Barrande, Suess, McCoy, Salter, Harkness, Nicol, Meneghini, myself, and others, were for the most part in a fragmentary condition, affording knowledge only of the simple stipe, the structure of its parts, and the arrangement of the cellules. From these fragments however we have derived the generic characters; while the modifications in form, and the order and relations of cellules, have furnished means of specific distinction in the greater proportion of those described.

In maintaining the generic term *Graptolithus* for the forms which have the nearest relations with those to which the term was originally applied by Linnæus, M. Barrande has proposed two sub-genera, characterized by the presence of a single series, or of two parallel series of cellules, under the names of *Monoprion* and *Diprion*. The latter term having been applied to a genus of insects, the name *Diplograptus* * of McCoy has generally been adopted.

The distinction indicated would at one time have expressed a character perfectly trenchant; but the discovery of such forms as *G. ramosus* † and *G. furcatus*, shows the occurrence of both a single and a double series of cellules upon the same stipe, or, more properly, shows the basal portion consisting of a stipe, with two parallel ranges of cellules. The stipe, dividing at some distance above its origin, is continued as two simple stipes, each with a single range of cellules. These cellules are on the outer margin, and are a continuation without interruption from those of the lower part of the stipe. Including these therefore in the same group with *G. pristis*, the subdivision indicated would have less value for the purposes of study; but I believe these latter forms may be separated on other grounds, as will be shown farther on; so that with our present knowledge we may still

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* In the genera proposed by myself, I have chosen the termination *graptus* instead of *grapsus*, since the latter termination is in use in the nomenclature of crustacea.

† The subdivision of this species beyond the first bifurcation, represented in the Palæontology of New York, vol. i, pl. lxxiii, fig. 3, is erroneous; the specimen consists of two individuals, the base of one being placed directly in the axil of the other.

recognize *Diprion*, = *Diplograptus*, as a well-marked and clearly-defined sub-generic group of the *Graptolithus* proper, having such forms as *G. pristis* among the typical species.

Mr. Geinitz has more recently proposed the name *Monograptus* to include *Monoprion* and *Rastrites* of Barrande; placing under this genus, as his typical species, *G. sagittarius* of Hisinger, which is the typical form of *Graptolithus* of Linnæus.

The genus *Cladograptus* * is also proposed by Mr. Geinitz, to include the species *G. ramosus* and *G. furcatus*, Hall, *G. Murchisoni*, Beck, *G. serra*, Brong., *G. Forchhammeri*, Geinitz, and *G. sextans* and *G. serratulus*, Hall. At the same time the British palæontologists, adopting the name *Didymograptus*, McCoy, place under that genus *G. Murchisoni*, Beck, *G. caduceus*, Salter, *G. sextans*, Hall, *G. geminus*, Hisinger, *G. hirundo*, Salter, and other similar forms. Those which are made the typical forms of the genus by Geinitz are the "species *gemellæ*" of Bronn, who included under that term the *G. geminus*, Hisinger, and *G. Murchisoni*, Beck, which are by no means nearly related to *G. ramosus* or *G. furcatus*. The first-named two species, which were the earliest known of that character, and regarded as the typical forms of *Didymograptus*, are similar to *G. bifidus* and *G. extenuatus* of this memoir, which differ from the other species on plates i, ii, and iii, only in the lesser divergence of the stipes.

Very recently Mr. Salter has proposed a further subdivision of the graptolites under the name *Tetragraptus*, "a kind of double *Didymograptus*," of which *G. bryonoides* is made the typical species; and *G. quadribrachiatus* is referred to the same genus. He also proposes *Dichograptus* for those having the "fronds repeatedly dichotomous from a short basal stipe into eight, sixteen, twenty-four, or more branches, each with a single row of cells." "But the main character which distinguishes *Dichograptus* is the presence of a corneous plate † which envelopes all the lower part of the branches, and which is not known in any other genus of the group; it has not indeed been seen in more than two or three species of *Dichograptus*, but it may not in all cases have been preserved." ‡

These subdivisions may be of some value when the entire frond and all its appendages are preserved, but unfortunately this is rarely so; and when we have but fragments of the stipes or branches, there is no force

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* Cladograpsus, Geinitz. Syn. *Graptolithus auctorum; species gemellæ*, Bronn. (Die Versteinerungen der Grauwacken formation in Sachsen, etc. Heft. i, *Graptolithen*, p. 29.) Monograpsus, id., ibid., p. 42. Syn. *Monoprion* et *Rastrites*, Barrande; *Graptolithus*, Suess.

† First discovered in the graptolites of the Quebec group at Point Lévis.

‡ Quarterly Journal of the Geological Society, vol. xix, p. 136.

or value in the application of these terms: we are thus reduced to the necessity of adopting the old term *Graptolithus*. Again, the value of *Didymograptus* I conceive to be pretty well illustrated in the case of *G. caduceus*, the original of which is cited from Lauzon, Canada.* After studying the large collections of graptolites made by the Canadian Geological Survey, I am compelled to believe that the *G. caduceus* was founded upon such forms as I have represented on plate xvi, figs. 22, 23, and 24; for we have no two-stiped species or forms of "*Didymograptus*" with a pedicle or radicle so long as that represented in the figures of Mr. Salter, nor any one so abruptly recurved; and I regard the apparent radicle in the two examples figured as simply one of the four stipes imbedded in the shale, and exhibiting its non-celluliferous margin and a small portion of its width, as I have shown in the figures cited.

Other varieties of this form show only the two simple stipes, with a slight process in the centre. We have therefore a "*Tetragraptus*" in a condition undistinguishable from a "*Didymograptus*"; and the same may happen in *G. bryonoides*, as shown in plate iv, fig. 5, where the quadripartite stipe is separated into two; and in the separated stipes it is impossible to know if there have been two, four, or eight in the entire individual. With regard to those fronds which are repeatedly dichotomous, forming the genus *Dichograptus*, of which the distinguishing character is the central "corneous plate which envelopes all the lower part of the branches," we may remark, that we have three or four species of the four-stiped form, or "*Tetragraptus*" with the central corneous plate; while we have four species which are not known to possess it. Of the two eight-stiped species known, one has the central corneous plate or disc, and the other was probably destitute of such an appendage. In *G. Logani*, with its numerous simple stipes, the central corneous plate is usually present, though not in all examples; while *G. multifasciatus*, with more numerous simple stipes than *G. Logani*, is not known to have a central corneous disc, and, from its mode of growth, probably never possessed such an appendage. From the irregularity of growth in the *G. abnormis*, I infer that there was no central plate.

In all the properly-branching species where the initial point is known, as in *G. flexilis*, *G. rigidus*, and *G. Milesi*, no such central plate has ever been seen; nor has it been shown in any European species, so far as I know. The frequently-bifurcating stipes, similar to the one originally proposed by Mr. Salter † as the type of *Dichograptus*, are not known to possess the central corneous disc.

Although entirely willing to accept and adopt such subdivisions of the graptolites as will aid in determining their zoological character and

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* *Graptolithus caduceus*, Salter; Quarterly Journal of the Geol. Society, vol. ix.

† Geologist, vol. iv, p. 74, 1861.

relations, their geological value, or indications of differences in mode of development, I do not appreciate at the present time the force and value of the proposed generic subdivisions for the two, four, and eight-stiped species, or the presence or absence of a central corneous disc as indicating generic distinctions; since it is impossible to obtain any aid from such designations for the references of the numerous fragments which are the ordinary form and condition in which we find the graptolites, and in which they must generally be studied.

The form, mode of growth, and arrangement of cellules in all these several proposed genera, are so identical in plan as to afford no means for generic separation; and although the same is true of the properly-ramose forms, yet I conceive it might have been convenient to adopt a term (*Dichograptus* or *Cladograptus*) indicating the ramose character of the stipes, regarding as true branches only the subdivisions which take place after the commencement of the cellules.

The genus *Nereograptus** of Geinitz, proposed by that author to include such forms as *Nereites*, *Myrianites*, and *Nemertites* of Murchison, and *Nemapodia* of Emmons, etc., can scarcely be admitted into the family of Graptolitidæ, since all the American species referred to the first three named genera have no texture or structure like graptolites, and (as I have elsewhere shown) appear to be referable to the tracks or trails of some marine worms or other animals upon the sea-bottom; while *Nemapodia* is simply the trail of an existing slug upon the slightly lichen-covered surfaces of the slates.†

The genus *Glossograptus* of Emmons is founded upon a species of *Diplograptus* with ciliate appendages on the cell-margins; and no characters are given to show its generic distinction. The typical species of *Nemagraptus* (*N. elegans*) is apparently a part of an individual of *Graptolithus gracilis*, or of some similar species; while the relations of the second species of the genus (*N. capillaris*), an elongate, flexuous, filiform body with a few branches at irregular intervals, can scarcely be determined from the figure given.

The typical and only species of *Staurograptus* ‡ of the same author is a very remarkable form of extremely minute proportions. Its mode of growth and subdivision of stipes, if accurately represented in the figure, are unlike anything known among this family of fossils, and it merits generic distinction.

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* *Nereograpsus:* Die Verstein. Grauwacken formation, etc., Graptolithen, p. 27.

† These markings can be easily removed from the surface of the laminæ by washing with water; and they can be traced over the exposed surfaces of the edges of the successive laminæ.

‡ *Glossograpsus*, *Staurograpsus*, *Nemagrapsus:* Emmons, American Geology, part ii, pages 108 and 109.

The term *Diplograptus* is properly applied to such forms as *Graptolithus pristis*, Hisinger, *G. palmeus*, Barrande (excepting figs. 5 and 6), *G. foliaceus*, Murchison, and *G. pristiniformis* of this memoir; where the cellules are disposed in parallel ranges on the two sides of the central axis, and are of the same or similar form and arrangement with those of monoprionidian form *G. sagittarius*, and with others of that type, in which we include all the species of the first nine plates of this memoir; the reason for the proposed separation being in the double range of cellules only.

In the ordinary forms of *Diplograptus* (plate xiii, figs. 15–17), as in the ordinary monoprionidian types, the cellules are usually closely arranged, and overlapping each other for a part of their length. In a single species (*G. putillus*, from the Hudson River formation in Iowa), which has come under my observation in some well-preserved fragments, we have so far a modification of the general arrangement of the cellules that the apex of one barely reaches the base of the next succeeding. The stipe is a strong elliptical tube with a flattened central solid axis, the line of which is marked on the exterior by a longitudinal undulating groove (fig. 10, pl. A). The surface is strongly striated transversely, and the sides studded with tubular cellules, which are alternately arranged. These cellules are sub-oval, flattened on the side adjoining the body of the graptolite, curving on the exterior free portion, and obliquely flattened at the base just above the aperture of the cellule next below, as shown in the profile view (fig. 11, plate A). The exterior test of the common body is swollen in oblique undulations in the direction of the base of the cellules, or where the individual buds take their origin; and the axis is curved towards the opposite side, as shown in fig. 10, plate A.

The transverse diameter of the stipe is about two-thirds as great as the longer diameter. The celluliferous face of the stipe shows broad elliptical depressions; the lower side, for little more than half the height, being the sub-oval cell-aperture; while the upper part is the semi-oval flattened area at the base of the next succeeding cellule, as shown in fig. 11, plate A. In this case the cellules are shown to be separate and distinct tubes, closely pressed against the lateral walls of the stipe on one side, and communicating with the common canal by a slightly narrowed passage, as shown in figure 12, plate A, which represents a longitudinal section of the body. In a transverse direction the base of the cellule is wider than the aperture (fig. 11, pl. A).

Specimens of this character, on becoming flattened, would present a form where the cellules, though inclined against the common body, would not overlap each other, and where the margin of the cellule is directed backward instead of forward. Were these cellules to be prolonged, they would overlap the next in advance, presenting in this condition but a slight modification of the usual forms of *Diplograptus*. These deviations from

typical forms are so slight as to offer no sufficient ground for generic separation.

There are however a few examples, where the stipe is marked by a range of cellules upon each side of the central axis, which appear to be properly separated from *Diplograptus*, on account of the form and structure of the cellules. These are apparently quite unlike those of *G. pristis*, and others of that sub-genus. The *Graptolithus bicornis*, and two or three allied forms, when flattened in the shale, show, as already described, a simple semi-elliptical notch in the margin of the stipe, nearly rectangular to the axis. This is well shown in fig. 3, plate vi, of M. Barrande's memoir, and also in Mr. Salter's illustrations of *Graptolithus teretiusculus* of Hisinger.* It is represented, less perfectly, in the figures of Prof. Harkness,† and in most of my own figures on plate lxxiii of the first volume of the Palæontology of New-York. When compressed rectangularly to the cellules, the apertures are transversely oblong-oval; and the same form is shown when looking upon the celluliferous margin of an uncompressed stipe.

The structure of these stipes and their cellules has already been described in a preceding section, with reference to the figures illustrating the same. The *G. bicornis*, known in New-York and Canada, may be considered the type of a group of species of which we have two in the shales of Norman's Kill near Albany, one in Ohio, and a similar or identical form in the Utica slate at Collingwood in Canada West. I would include in the same group figs. 5 and 6 of plate iii, as well as figs. 7, 8, and 15, plate ii of M. Barrande's Memoir; *Graptolithus teretiusculus* of Hisinger; and those referred to the same species by Salter.‡ The *Diplograptus rectangularis* of McCoy ‖ is of the same type, as also figs. 1, 5, 10, 11, 12, etc., tab. ii, of Geinitz (*Graptolithen*); and I conceive that many, if not all of the scalariform specimens, belong to species of this character.

The *Graptolithus ramosus* has usually been arranged by authors under *Diplograptus*; the lower part of the stipe having a double range of cellules, while it is bifurcated above, with the cellules on the outer margin of each division, as already described; and a simple explanation of this condition has been offered by supposing that the solid axis has been separated after the death of the zoophyte. This however will scarcely afford a satisfactory argument when we find that all the specimens are in the same condition; that usually the division begins at a uniform distance from the base; and that, when entire, the divided portion much exceeds the

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* Quarterly Journal of the Geol. Society of London, vol. viii, pl. xxi, figs. 3 and 4.

† Id. Ibid., vol. vii, pl. i, fig. 11.

‡ Quarterly Journal of the Geological Society, vol. viii, pl. xxi.

‖ British Palæozoic Fossils, page 8, pl. xiii, figs. 8, 9, and 10.

simple undivided part of the stipe. Moreover, the species is recognized in this condition in the Hudson River formation in Canada, and has likewise been recognized in Great Britain; while a similar or identical form has been shown by Prof. McCoy to occur in Australia. We must therefore seek some other than an accidental cause for the explanation of this uniform bifurcation of the stipes of that species. In the meantime, it appears to me highly proper to suggest its separation from *Diplograptus*.

On farther comparison, we shall find that *G. ramosus* is not quite alone in its peculiar characters. In *G. furcatus* there are a few cellules at the base of a simple stipe below its bifurcation; and in *G. sextans*, the lower part of the stipe is simple, the division taking place above the first cellule; but in entire individuals the division is never from the initial point, as we see it in *G. bifidus* and *G. nitidus* of this memoir.

Now these first-named species, as well as *G. ramosus*, have cellules of a peculiar form; and looking still farther, we find a similar form of cellule in *G. Forchhammeri*, Geinitz, and *G. divaricatus*, Hall, two species which are divided from the base, having a single range of cellules upon the outer sides of the stipe. I believe it will be found, moreover, that all the graptolites with cellules on the lower side of the stipes (in reference to the initial point or radicle) have these parts of the same form as *G. ramosus*, and very unlike the *G. pristis* and allied species. Nor are the cellules on the simple or divided portions of the same stipe, or on those which are entirely divided and upon the lower side, at all like the cellules of *G. priodon*, *G. geminus*, *G. Murchisoni*, or any of the allied forms illustrated in this memoir, to which the term *Didymograptus* has been applied; nor can they be properly united with them. The form of the cellules is always sufficiently distinctive even in fragments of the stipes; and this feature, together with the mode of development or growth, seems to me sufficient to sustain a generic distinction.

The genus *Retiolites* is described by M. Barrande as having no central solid axis, but with a single internal canal occupying the median portion of the polyp. The prevailing form of the stipe is somewhat concavo-convex, with the centre of the concave side prominent; the entire surface is covered by a net-work of corneous substance, and the cell-apertures are quadrangular.

Prof. Geinitz has given some further illustrations, showing more emphatically a longitudinal axis on the convex side, to which are joined the cell-partitions; while he regards the common body as occupying the prominent central portion of the concave face of the stipe, and shows the cell-partitions terminating before reaching the centre, leaving a space occupied by the width of the common body. This he represents as covered by a net-work of slightly different texture from that of the other portions of the substance.

The Canadian specimens which I have referred to this genus are so extremely attenuated that it is impossible to determine the details of structure, and the surface-characters are obscure. Thus far we have no American specimens in a condition to afford the means of elucidating some obscurities which seem to me still to exist in regard to the intimate structure of this genus. The species of the Clinton formation is extremely compressed; and while some specimens show the cell-divisions terminating at a distance from the centre, yet, after protracted and repeated examinations, my most critical observations result in showing only the structure which is illustrated on plate B, figs. 20 and 21.

On one side we have an external, cylindrical, solid axis, to which the cell-divisions are joined; but these latter show only filiform cylindroid processes, extending from the axis to the cell-margin, and projecting a little beyond the margin of the stipe. The only other aspect which we observe in this species is that of an undulating or zigzag filiform axis on *the opposite side*, to which the cell-partitions are joined, as in fig. 21, plate B. We know this to be on the opposite side or within the stipe, as it is sometimes seen overlying the straight axis and cell-partitions.

At the junction of the cell-divisions with the zigzag axis there are other processes of similar character, projecting upward and outward from the axis, all of nearly equal length, but apparently broken at their extremities. I have not been able to determine any connection between these and other parts of the skeleton, but we have the two structures very clearly represented in the figures referred to. I have supposed that similar processes may have extended to the opposite side, from the junction of the cell-partitions with this undulating axis, either joining the cell-divisions or the straight axis; but after long investigation I have been unable to find satisfactory evidence of such connection. The cell-apertures are surrounded by thickened margins, and the only appearances of cell-partitions are the sub-external cylindrical extensions from the aperture to the axis. Neither the species of the Quebec group nor that of the Clinton formation, in any of the specimens seen, are in a condition to show evidence of the concavo-convex character of the stipe represented by M. Barrande and Prof. Geinitz.

The species of *Retiograptus*, while having some characters in common with *Retiolites*, do not possess the reticulated structure of the test in either of the described species. There yet remains some obscurity in regard to the internal structure of this genus, which can only be satisfactorily explained by the examination of better-preserved specimens. Nevertheless, in its general form, structure, and mode of growth, it is shown to be quite distinct from other graptolitic genera. The three species referred to this genus present differences which can only be reconciled by supposing that the two sides of the stipe are very unlike each other in form and external characters, as in *Retiolites*.

The species for which I have proposed the genus *Phyllograptus*, present close analogies with the typical form of *Diplograptus* in the character of test and form of cellules. These, in their aperture and form, are nearly quadrangular; and the cell-partitions are apparently continuous between the cellules, and reach nearly to the central axis; characters which we find in *Diplograptus*. These forms, in their great lateral extension, depart widely from their analogues; but they differ more essentially in their cruciform mode of growth, presenting an arrangement of parts, as if four simple stipes (like those of *G. bryonoides* or *G. Bigsbyi*) were joined together by the coalescing of the solid axes. In this latter respect, and in their great development in width, they differ most essentially from all the other genera of this family of fossils. These forms are fully illustrated on plates xv and xvi of this memoir.

In the typical species of *Dendrograptus*, as illustrated under the generic description, and in some of the species on plate xvii, we have a wide departure from the typical forms of *Graptholithus*, as developed in the characteristic species of the genus (plates i–ix). The strong stem or trunk, which is free from cellules, and which has apparently been fixed at the base; the irregular branching, which has no bilateral, and apparently no definite arrangement, such as observed in all the forms of true *Graptolithus*, are strong points of dissimilarity, and furnish characters for generic distinction. The stem and branches are unequally striated longitudinally, but the form of the celluliferous branches and of the cellules offers no important difference (except in the smaller dimensions) from those of the stipes or branches of the usual form of graptolites with a single series of cellules. In one species referred to this genus (the *D. gracilis*) there is some departure from the typical form of cellules, and the body of the stipe is contracted at intervals, while the form of cellule and cell-aperture is not unlike some of the Sertularians.

The genus *Callograptus* offers forms which are intermediate between true *Dendrograptus* and *Dictyonema*. In these species, the forms of the cellules have not been fully determined. They are marked in one species by slight oval pustules, or oval depressions, upon the extremely compressed surface of the stipe; but it cannot be satisfactorily shown that this appearance indicates the normal condition of the cellule or the aperture. If the true form be in reality so far different from the usual character of the Graptolitidæ as these appearances indicate, it may be found necessary to separate them from this family.

The genus *Dictyonema* is restricted to such forms as have the numerous stipes and branches connected by a transverse process, and the whole united in a flabelliform or funnel-shaped frond, without elongate stem or trunk. The stipes and branches are irregularly striated externally, consisting of a corneous envelope, as in ordinary graptolites; but I have not

been able to determine clearly the existence of a solid axis. The cellules are indicated by angular processes or cell-denticles on the inner side of the branches; as shown in fig. 5 of plate B.

In the genus *Rastrites* of Barrande the distinguishing features are the slender cylindrical stipes or branches, with distant slender tubular cellules.

The few species of *Thamnograptus* known consist of cylindrical or sub-cylindrical stipes, with slender elongate alternating pinnulæ or branchlets. No evidence of cellules has been observed in any of the specimens.

The peculiar forms for which I have proposed the name *Ptilograptus*, consist of branching stems, which, in all their divisions, are studded on each side, in alternating order, with narrow pinnulæ. These are sometimes extremely slender, or even capillary in their dimensions. In one species I have detected elliptical spots upon one face of the pinnulæ, which are slightly flattened, and I infer that these are the cell-apertures. The substance of the test is corneous, and there is an internal solid axis. Although I have placed these forms under the Graptolitidæ with some hesitation, the form of cellules may perhaps render a separation desirable; but with only our present information, such a separation cannot at this time be made.

The genus *Inocaulis* was proposed for some flattened stipes with a scabrous surface, which have the appearance of denticles upon the margins. These stipes grow in close groups or tufts, and are bifurcating or branched in their upper portions. No positive evidence of cellules has been observed. The presence of denticles, together with a corneous or carbonaceous substance, have induced me to place this fossil among the Graptolitidæ.

There is still another form known, which may be doubtfully classed among the Graptolitidæ. It consists of a slender flexible median rachis, on each side of which are placed, in alternating order, slender flattened pinnulæ, which are of nearly equal width throughout, and are themselves flexuous. Upon one side of the rachis are minute points or dots, which have apparently been the cell-apertures. The test is a black corneous or carbonaceous substance, but there is no evidence of a solid central axis. These bodies are numerous in some shaly beds of the age of the Trenton limestone, at Plattville, Wisconsin. For these I have proposed the name of *Buthograptus*.*

Associated with the preceding forms, there are some stems of corneous or carbonaceous texture, frequently branched, the branches again dividing, and sometimes, if not always, in whorls; in one of which six divisions were counted. The general form of the body is not unlike that of *Dendrograptus*, but the branches are more slender, and ramify in a different manner, while there are no visible cellules. Without farther knowledge,

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* Report of Progress of the Geological Survey of Wisconsin for 1860, p. 19; communicated January 1st, 1861.

I refer these fossils, with hesitation, to the genus *Oldhamia* (*O. fruticosa*, Hall).

The variety of form and mode of development among the graptolites is shown, by these collections from the Quebec group, to be much greater than had ever before been supposed. The number of species which have been traced to their origin, and whose mode of growth has been verified, is probably larger than in all the collections heretofore made ; and, together with those before known, enables us to give a very full exposition of the characters of this family of fossils.

SYNOPSIS OF THE GENERA OF GRAPTOLITIDÆ.

I.

Species consisting of stipes or fronds, with a bilateral arrangement of the parts ; a solid axis, with a common canal extending along each series of cellules.

<table>
<tr><td colspan="2">1. The successive buds developed in tubular cellules, which are usually in contact for a greater or less proportion of their length, and inclined towards the axis.</td></tr>
<tr><td>a. Cellules in single series along one side of a common solid axis. Stipes, two or more, from a common origin, with or without a central disc. Sub-genera Monoprion,* Didymograptus, Monograptus, Tetragraptus, etc.
b. Cellules on one side of slender branches, which are developed on one or two sides of a long slender axis or rachis, the free extremities of which are likewise celluliferous. Ex. G. gracilis and G. divergens.
c. Cellules developed in parallel arrangement on two sides of a common solid axis. Stipes narrow elongate. Sub-genus Diprion, = Diplograptus.</td><td>GRAPTOLITHUS, Linnæus.</td></tr>
<tr><td>d. Cellules developed in a cruciform arrangement on the four sides of a common or coalescent axis. Stipes elliptical or sub-elliptical.</td><td>PHYLLOGRAPTUS, Hall.</td></tr>
<tr><td>2. Cell-apertures excavated in the margins of the stipes, without tubular or cup-form extension ; the cell-apertures upon one or both sides of the stipe. Graptolithus bicornis and others.</td><td>CLIMACOGRAPTUS, Hall.</td></tr>
<tr><td colspan="2">3. Solid axis eccentric or sub-exterior, with cellules developed in parallel ranges on opposite sides of the stipe, and in contact throughout their entire length.</td></tr>
<tr><td>a. Known only as separate stipes, with reticulate test.</td><td>RETIOLITES, Barrande.</td></tr>
<tr><td>b. Occurring as simple stipes, and as compound fronds ; test smooth.</td><td>RETIOGRAPTUS, Hall.</td></tr>
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* Should it be proved that there exist simple stipes with a single range of cellules, the definition of this section will require to be modified, or a new sub-section made to include such forms.

II.

Species having a common trunk or stem, or growing in sessile groups of stipes from a common origin, without distinct bilateral arrangement of the parts. Cellules in single series on one side of the stipes or branches, and arranged along a common canal or axis.

1. Branches free (i. e. not connected by transverse bars;) cellules in contact or closely arranged.	DENDROGRAPTUS, *Hall.*
2. Branches unfrequently and irregularly connected by transverse processes.	CALLOGRAPTUS, *Hall.*
3. Stipes and branches more or less regularly united in a reticulate frond, without elongate stem.	DICTYONEMA, *Hall.*
4. Stipes round or flattened, growing in groups, and bifurcating above; margins denticulate; surface rough or scaly. [*The relations of this genus are not fully determined.*]	INOCAULIS, *Hall.*

III.

Slender cylindrical branches, with tubular cellules arranged in single (or in double ?) series. Cellules not in contact in any part of their length. RASTRITES, *Barrande.*

IV.

Species having a common axis or rachis, with slender lateral alternating branchlets. Cellules unknown. THAMNOGRAPTUS, *Hall.*

V.

Species having a common axis, more or less frequently bifurcating, with pinnulæ closely and alternately arranged on the opposite sides; cell-apertures on one face of the pinnulæ. PTILOGRAPTUS, *Hall.*

VI.

A simple flexuous rachis, with slender flexuous flattened pinnulæ arranged in alternating order at close and regular intervals on the two sides. Cell-apertures unknown, or circular. BUTHOGRAPTUS, *Hall.*

VII.

Strong stems, which are numerously branched. Branches and branchlets slender, arranged in whorls. Cellules undetermined. OLDHAMIA [?], *Forbes.*

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§ VII.—GEOLOGICAL AND GEOGRAPHICAL DISTRIBUTION OF THE GRAPTOLITES IN THE ROCKS OF CANADA AND THE UNITED STATES.

Until the remarkable discovery of the graptolites of Point Lévis in 1854, the chief repository of these fossils known in American rocks was in the shales of the Hudson River valley.

The position assigned to the rocks of the Hudson River valley was the superior part of the lower division of the Silurian system. In this respect, the horizon of the Graptolite beds corresponded with those of Ireland, from which these fossils had been described by General Portlock ;* and with the position assigned to those in Sweden, as well as with those of the

* Geological Report on Londonderry, etc., page 317–322.

Llandeilo and Caradoc formations of Great Britain. The graptolites of Bohemia are from strata referred by M. Barrande to the base of the superior division of the Silurian system; and those of Saxony were regarded as from the same horizon.

In 1850, M. Barrande expressed the opinion that the epoch of the graptolites was posterior to that of the "Faune Primordiale" in Bohemia and Scandinavia; while their association with primordial fossils in the Malvern Hills and at Snowdon, indicated the earlier appearance of these zoophytes in Great Britain. A comparison of all the published information on the subject at that time induced M. Barrande to conclude, as a general fact, that the graptolites had made their earliest appearance in the regions of the northwest; and that their highest development in central Europe had only been reached at a later period, or at the base of the upper division of the Silurian system.

The investigations in the Geological Survey of New-York had proved in a pretty satisfactory manner that no graptolites proper occurred above the horizon of the Clinton group, though *Dictyonema* (supposed to belong to the same family) had been found in the Niagara formation. The species at that time known ranged from the higher strata of the Lower Silurian, to the lower beds of the Upper Silurian division; and both in Europe and America, these fossils were regarded as of eminently Silurian character, and unknown in any later geological periods.

The discovery of a graptolitic species in the Potsdam sandstone of the St. Croix River valley, by Dr. H. A. Prout, in 1850, was the first indication of the occurrence of this family of fossils at a lower horizon than that of the Hudson River and Trenton formations.

Before the discovery of graptolites in the shales of Point Lévis, these rocks were supposed to belong to the age of the Hudson River formation; and although it was shown that the graptolites were all of different species from those previously described, yet they appeared to offer only corroborative evidence in support of the previously entertained opinion regarding the age of the strata. It was only at a later period, and from the discovery of numerous other fossils in the same formation, some of them having a primordial aspect, that its higher antiquity was suspected.

The shales of Point Lévis, with their associated limestones and sandstones, since termed the Quebec group, are now regarded as embracing the period from the Calciferous sandstone to the Chazy limestone, inclusive. This epoch therefore is entirely anterior to that of the Hudson River formation, and a careful comparison of all the species of graptolites has shown that no identical species occur in the two series of rocks.

In the present state of our knowledge, we recognize the Graptolitidæ as beginning their existence at the period of the Potsdam sandstone. The greatest development of the family, both in genera and species, is

found to be at the epoch of the Quebec group. Several genera and a few species are known in the Trenton formation; and a greater development, embracing most of the genera and many species, occurs at the period of the Hudson River formation in Canada and the United States. In the Clinton strata we have a single species of *Graptolithus*, and a *Retiolites;* while *Dictyonema* and *Inocaulis* occur in the Niagara beds. In all the subsequent geological formations we have found no true graptolites, and the only representatives of the family consist of fragments of *Dictyonema*, belonging to a few species. These occur in the Upper Helderberg and Hamilton formations, above which we do not yet know a species of any genus referable to this family of fossils. The genus *Graptolithus* has its upper limit in the shales of the Clinton formation, and all others of the family, except *Dictyonema*, are restricted to the Silurian system.

The geographical distribution of the Graptolitidæ is not in all respects coincident with the extent of the geological formations. *Dendrograptus* occurs in the Potsdam sandstone of the St. Croix valley; but neither this nor any other graptolite is known in other localities of the sandstone, so far as I am aware. The species of the Quebec group, numbering more than all the other formations together, have been identified for a longitudinal extent of about 900 miles; Point Lévis, Orleans Island, St. Anne's River (Gaspé), and the western part of Newfoundland, being the principal localities. But although the Quebec group is known to extend into Vermont and along the eastern counties of New-York, I am not aware that graptolites have been found in any authentic localities of that formation.* Thus far, therefore, these fossils of the group are known only in Canada and Newfoundland.

The Trenton limestone, while furnishing two species of *Graptolithus* in New-York, gives at the west no specimens of the genus proper; but we have one *Dictyonema*, a *Buthograptus*, and an *Oldhamia*? in the same formation in Wisconsin, though not elsewhere known.

The Utica slate at Utica abounds in the remains of graptolites, and these fossils are of frequent occurrence at Oxtungo Creek, in the valley of the Mohawk. It is probable that some of the localities referred to the Hudson River formation, may be in the Utica slate, which, owing to the disturbed condition of the strata, is not separable from the succeeding slates.

In the Hudson River formation, the characteristic graptolites, of numerous species, have been found, in greater numbers than elsewhere, at Norman's Kill near Albany; but they occur at Stuyvesant's Landing, and at the

* A single branching form, the *G. Milesi*, has been published in the Geological Report of Vermont. The specimen was found in a boulder of slate, but it is probably of the Quebec group.

city of Hudson; while some species have been found near Baker's Falls on the Hudson River, and at Ballston and Saratoga, New-York. Graptolites of species identical and similar to those of the Hudson River formation have been found by Dr. Emmons in the shales of Augusta County, Virginia, and also in Tennessee.

The more characteristic species of the formation, *G. pristis*, *G. bicornis*, *G. ramosus*, *G. sextans*, *G. divaricatus*, and *G. gracilis*, have been recognized among the collections of the Canada Geological Survey, from the Hudson River formation in the valley of the St. Lawrence. In the extension of this formation westward, a few species only have been found in central and western New-York; among these, *G. pristis* is the most common, while *G. bicornis* is more rarely seen. In Ohio, we have no more than two species from rocks of this formation; while extensive collections from the same formation in Wisconsin and Iowa have afforded only three species (all unlike those from Cincinnati), and one of these has been found in beds of the same age in Illinois. In the catalogue of fossils appended to the Geological Report of Missouri, no mention is made of the occurrence of Graptolitidæ in any of the formations.

The great accumulation of materials at the epoch of the Hudson River formation has been in the direction from northeast to southwest; and along this line the black and dark colored graptolite schists, alternating with coarser beds, have collected in much greater mass than in any other part of its extent. In the northwestern counties of New-York, Jefferson and Oswego, where the formation has a thickness of more than a thousand feet, the graptolites are comparatively few in species, and not of common occurrence. The gradual attenuation of the rocks of this formation towards the west is marked by the extreme paucity of graptolitic forms.

The graptolites of the Clinton strata have not, to my knowledge, been found beyond the limits of western New-York; and both their horizontal and vertical range is very restricted. The graptolitic forms of the Niagara formation (*Dictyonema* and *Inocaulis*) are very limited in their geographical extent.

The *Dictyonema* of the Upper Helderberg and Hamilton formations are known to occur in New-York and in Ohio; and in the northwest a species has been found in the Upper Helderberg limestone on Mackinac Island.

This distribution of the Graptolitidæ, as well as their general association with other fossils, together with the nature of the sediments, would indicate the proximity of the coast-line as their habitat, and as the zone of their greatest development.

Table showing the Vertical Distribution of the Genera of the Family of Graptolitidæ.

Genera.	Potsdam.	Calciferous, Chazy, Quebec.	Trenton.	Hudson.	Medina.	Clinton.	Niagara.	Onondaga.	Lower Helderberg.	Upper Helderberg.	Hamilton.	Chemung.	Carboniferous.
Graptolithus, Sub-genus Monoprion	..	*	*	*	..	*	..	..	..	..	..	..	..
Graptolithus, Sub-genus Diplograptus	..	*	*	*	..	..	..	..	..	..	..	..	..
Climacograptus*	..	*	..	*	..	..	..	..	..	..	..	..	..
Phyllograptus	..	*	..	..	..	..	..	..	..	..	..	..	..
Retiolites	..	*	..	..	..	*	..	..	..	..	..	..	..
Retiograptus	..	*	..	*	..	..	..	..	..	..	..	..	..
Dendrograptus	*	*	..	..	..	..	..	..	..	..	..	..	..
Callograptus	..	*	..	..	..	..	..	..	..	..	..	..	..
Dictyonema	..	*	..	.	..	..	*	.	..	*	*	..	..
Ptilograptus	..	*	..	..	..	..	..	..	..	..	..	..	..
Thamnograptus	..	*	..	*	..	..	..	..	..	..	..	..	..
Rastrites	..	..	..	*	..	..	..	..	..	..	..	..	..
Inocaulis	..	..	..	..	..	..	*	..	..	..	..	..	..
Buthograptus	..	..	*	..	..	..	..	..	..	..	..	..	..
Oldhamia ?	..	..	*	..	..	..	..	..	..	..	..	..	..

The pre-eminence of the Quebec group, as the period of the greatest development in the Graptolitidæ, is shown in the above table. Of the fifteen genera and one sub-genus here enumerated, eleven are known in this period; while four genera, viz., *Phyllograptus*, *Dendrograptus*, *Callograptus*, and *Ptilograptus*, are not at present known in any higher position than the Quebec group, though one of them occurs in the Potsdam Sandstone. All those genera having the nearest relations with *Graptolithus* proper occur in this group, and the species of that genus found in it are more numerous than in all the subsequent formations, so far as at present known.

In addition to circumstances originally favorable to their development and growth, the subsequent conditions presented during the period of the Quebec group in Canada seem to have been equally favorable to the preservation of graptolites, and in no other formation have they been found with all their parts so entire.

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* Under this genus, in the following table I have introduced a sub-genus, *Dicranograptus*.

TABLE SHOWING THE GEOLOGICAL DISTRIBUTION OF THE SPECIES OF GRAPTOLITIDÆ IN CANADA AND THE UNITED STATES.

GENERA AND SPECIES.		Potsdam.	Calciferous, Chazy, } Quebec.	Trenton.	Hudson River.	Medina.	Clinton.	Niagara.	Onondaga.	Lower Helderberg.	Upper Helderberg.	Hamilton.	Chemung.	Carboniferous.
Genus GRAPTOLITHUS, Linnæus.														
(Sub-genus MONOPRION, Barrande.)														
G. abnormis,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
alatus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
arcuatus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
bifidus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
Bigsbyi,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
bryonoides,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
Clintonensis,	H.	..	..	..	..	..	*	..	..	..	..	..	..	..
constrictus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
crucifer,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
denticulatus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
divergens,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
extensus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
extenuatus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
flaccidus,†	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
flexilis,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
fruticosus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
gracilis,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
Headi,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
indentus,	H	..	*	..	..	..	..	..	..	..	..	..	..	..
Logani,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
Logani, var.,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
Milesi,‡	H.	..	* ?	..	..	..	..	..	..	..	..	..	..	..
multifasciatus,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
nitidus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
octobrachiatus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
octonarius,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
patulus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
pennatulus,	H	..	*	..	..	..	..	..	..	..	..	..	..	..
quadribrachiatus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
ramulus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
Richardsoni,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
rigidus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
sagittarius,	H. (His. ?)	..	..	..	*	..	..	..	..	..	..	..	..	..
serratulus,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
similis,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
tenuis,	H. (P. ?)	..	..	..	*	..	..	..	..	..	..	..	..	..
(Sub-genus DIPLOGRAPTUS, McCoy.)														
G. amplexicaulis,	H.	..	..	*	..	..	..	..	..	..	..	..	..	..
angustifolius,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
ciliatus,	E.	..	..	..	*	..	..	..	..	..	..	..	..	..
inutilis,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
marcidus,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
mucronatus,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
peosta,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
pristis,	H. (His. ?)	..	..	..	*	..	..	..	..	..	..	..	..	..
pristiniformis,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
putillus, n. s.,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..

† Utica slate. ‡ From a boulder.

TABLE SHOWING THE GEOLOGICAL DISTRIBUTION OF THE SPECIES OF GRAPTOLITIDÆ IN CANADA AND THE UNITED STATES.—(Continued.)

GENERA AND SPECIES.		Potsdam.	Calciferous, Chazy, } Quebec.	Trenton.	Hudson River.	Medina.	Clinton.	Niagara.	Onondaga.	Lower Helderberg.	Upper Helderberg.	Hamilton.	Chemung.	Carboniferous.
(Sub-genus DIPLOGRAPTUS, McCoy.)—(Con'd.)														
G. quadrimucronatus, †	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
secalinus,	Eaton.	..	*	..	..	..	..	..	..	..	..	..	..	..
spinulosus,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
Whitfieldi,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
(unnamed,) n. s.		..	..	..	*	..	..	..	..	..	..	..	..	..
Genus CLIMACOGRAPTUS, Hall.														
C. antennarius,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
bicornis,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
parvus, n. s.,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
typicalis, n. s.,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
(Sub-genus DICRANOGRAPTUS, Hall.)														
C. divaricatus,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
furcatus,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
ramosus,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
sextans,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
Genus PHYLLOGRAPTUS, Hall.														
P. angustifolius,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
Anna,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
ilicifolius,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
typus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
Genus RETIOLITES, Barrande.														
R. ensiformis,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
venosus,	H.	..	..	..	..	..	*	..	..	..	..	..	..	..
Genus RETIOGRAPTUS, Hall.														
R. eucharis, ‡	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
Geintzianus,	H.	..	..	..	*	..	..	..	..	..	..	..	..	..
tentaculatus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
Genus DENDROGRAPTUS, Hall.														
D. diffusus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
divergens,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
erectus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
flexuosus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
fruticosus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
gracilis,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
Hallianus,	Prout.	*	..	..	..	..	..	..	..	..	..	..	..	..
striatus,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
Genus CALLOGRAPTUS, Hall.														
C. elegans,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..
Salteri,	H.	..	*	..	..	..	..	..	..	..	..	..	..	..

† Utica slate. ‡ Utica slate, Lake St. John.

TABLE SHOWING THE GEOLOGICAL DISTRIBUTION OF THE SPECIES OF GRAPTOLITIDÆ IN CANADA AND THE UNITED STATES.—(Continued.)

GENERA AND SPECIES.		Potsdam.	Calciferous, Chazy, } Quebec.	Trenton.	Hudson River.	Medina.	Clinton.	Niagara.	Onondaga.	Lower Helderberg.	Upper Helderberg.	Hamilton.	Chemung.	Carboniferous.
Genus DICTYONEMA, Hall.														
D. cadens, n. s.,	H	..	..	..	..	..	..	..	..	..	..	*	..	..
fenestrata,	H	..	..	..	..	..	..	..	..	..	*	..	..	..
gracilis,	H	..	..	..	..	..	..	*	..	..	..	..	..	..
Hamiltoniæ, n. s.,	H	..	..	..	..	..	..	..	..	..	..	*	..	..
irregularis,	H	..	*	..	..	..	..	..	..	..	..	..	..	..
Murrayi,	H	..	*	..	..	..	..	..	..	..	..	..	..	..
Neenah,	H	..	..	*	..	..	..	..	..	..	..	..	..	..
quadrangularis,	H	..	*	..	..	..	..	..	..	..	..	..	..	..
retiformis,	H	..	..	..	..	..	..	*	..	..	..	..	..	..
Websteri,†	H	..	..	..	..	..	..	*	..	..	..	..	..	..
Genus PTILOGRAPTUS, Hall.														
P. Geinitzianus,	H	..	*	..	..	..	..	..	..	..	..	..	..	..
plumosus,	H	..	*	..	..	..	..	..	..	..	..	..	..	..
Genus THAMNOGRAPTUS, Hall.														
T. Anna,	H	..	*	..	..	..	..	..	..	..	..	..	..	..
capillaris,	H	..	..	..	*	..	..	..	..	..	..	..	..	..
typus,	H	..	..	..	*	..	..	..	..	..	..	..	..	..
Genus RASTRITES, Barrande.														
R. Barrandi,	H	..	..	..	*	..	..	..	..	..	..	..	..	..
Genus BUTHOGRAPTUS, Hall.														
B. laxus,	H	..	..	*	..	..	..	..	..	..	..	..	..	..
Genus INOCAULIS, Hall.														
I. plumulosa,	H	..	..	..	..	..	..	*	..	..	..	..	..	..
Genus OLDHAMIA [?], Forbes.														
O. fruticosa	H	..	..	*	..	..	..	..	..	..	..	..	..	..

† Nova Scotia.

§ VIII.—HISTORICAL NOTICE* OF THE GENUS GRAPTOLITHUS.

FOLIA GRAMINEUM	Bromel.
GRAPTOLITHUS GRAPTOLITES	Linnæus, Wahlenberg, Beck, Quenstedt, Murchison, Portlock, De Verneuil, Keyserling, Mather, Vanuxem, Emmons, Barrande, D'Orbigny, Geinitz, Suess, Meneghini, McCoy, Richter, Salter, Nicol, Harkness, Hall.
PRIODON	Nilsson.
ORTHOCERATITES	Wahlenberg, Schlotheim, Quenstedt, Geinitz.
LOMATOCERAS	Bronn, Eichwald.
PRIONOTUS	Nilsson, Hisinger.
FUCOIDES	Brongniart, Eaton, Emmons, Conrad.
PETALOLITHUS	Suess.
DIPRION (sub-genus)	Barrande.
DIDYMOGRAPTUS	McCoy, Salter, and others.
DIPLOGRAPTUS	McCoy, Salter, Harkness, etc.
MONOPRION (s.-gen.)	Barrande.
MONOGRAPTUS CLADOGRAPTUS	Geinitz, Emmons.
GLOSSOGRAPTUS NEMAGRAPTUS	Emmons.
TETRAGRAPTUS DICHOGRAPTUS	Salter.

A. D. 1727. The graptolites of Sweden were observed by Bromel, who regarded them as leaves of grasses. (*Act. Upsal.*)

1736. Linnæus established the genus *Graptolithus* in the first edition of his *Systema Naturæ;* and some years later, in the twelfth edition, introduced specific names, *G. scalaris* being the type of the genus. This form has been regarded by Wahlenberg, Geinitz, and Barrande as the *G. sagittarius*, compressed in a direction rectangular to the cellules. The *G. sagittarius*, Linn., is therefore regarded by the latter author as the veritable historical prototype of the genus *Graptolithus* and of the family of graptolites. For my own part, I consider the *G. scalaris*, so far as illustrations of that form have come under my observation, as a distinct type of the graptolite family.

1821. Wahlenberg considered the graptolites of Sweden as very slender orthoceratites. (*Nova Acta. Soc. Scien. Upsal*, vol. viii, pp. 92 and 93.)

1822. Schlotheim, participating in the opinion of Wahlenberg, described and figured a species under the name *Orthoceratites serratus.* (*Petrefakenkunde*, p. 56, pl. viii, fig. 3.)

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* From the earliest notice of the genus Graptolithus to the year 1850, I have added but little to that which has already been published by M. Barrande in his Graptolites of Bohemia.

1828. Ad. Brongniart described two species of graptolites from the Transition formation at "Pointe Lévi près Québec dans le Canada," as *Fucoides dentatus* and *F. serra.** (*Histoire des Végétaux Fossiles*, pp. 70 and 71, pl. vi, fig. 7–12.)

1829 [1831 ?]. F. Holl republished the description of *Orthoceratites serratus* of Schlotheim. (*Handbuch die Petrefacten.*, vol. ii, p. 234.)

18—? Prof. Nilsson recognized the graptolites as polyps belonging to the ceratophydians. He proposed to substitute the pre-occupied name of *Priodon* for that of *Graptolithus*. (See *Dr. Beck*, in *Murchison's Silurian System*, p. 696.)

1835. Prof. Bronn, adopting the opinion of Prof. Nilsson regarding the nature of graptolites, gave the name *Lomatoceras* (*Lethea Geognostica*, vol. i, p. 55, pl. i, fig. 13, *L. priodon*), at the same time arranging the species with the orthoceratites, etc.

1837. Hisinger described five species of graptolites from the rocks of Sweden, adopting the generic name *Prionotus*, created by Prof. Nilsson. Among these are two species of Linnæus, *P. sagittarius* and *P. scalaris;* to which he added the new species *P. pristis*, *P. folium*, and *P. convolutus*. (*Leth. Suecia*, p. 113, pl. 35.) In the second supplement to that work, published in 1840, two other species are added, under the names *P. geminus* and *P. teretiusculus;* the latter being of the type of *G. scalaris*. (Supp. ii, p. 5, pl. 38.)

1839. Sir Roderick Murchison described and figured in the Silurian System three species of graptolites, *G. Ludensis*, *G. Murchisoni*, and *G. foliaceus*. (*Sil. System*, p. 695.)

1840. Prof. Eichwald published a description of *Lomatoceras distichus*, a graptolite from the Silurian formation of Esthonia. (*Sil. Syst. in Esthland*, p. 101.)

1840. Prof. Quenstedt sought to re-establish the opinion that the graptolites are true orthoceratites. (*N. Jahrb. f. Min.*, p. 275.)

1842. Prof. Geinitz described and figured five species of graptolites under the names *G. foliaceus*, Murchison, *G. priodon*, Bronn, *G. Ludensis*, Murchison, *G. serratus*, Schloth., *G. scalaris*, Linn., and *G. spiralis*, Geinitz; regarding them as belonging to the Cephalopoda. (*N. Jahrb. f. Min.*, p. 697.)

1842. Vanuxem identified a graptolite of the Utica slate with the *Fucoides dentatus* of Brongniart. *Graptolithus dentatus*, Vanuxem, *G. pristis*, Hall, His.? (*Geol. Rep. 3d Dist. N. Y.*, p. 57, fig. 2.)

1843. Gen. Portlock, in his Geological Report, discussed the nature

* These species are probably identical with those which I have heretofore described as *G. pristiniformis* and *G. bryonoides*.

of the graptolites, recognizing them as true zoophytes, and indicating their analogy with Sertularia and Plumularia. He suggested that the species may form several genera, belonging perhaps to different orders. The species described and enumerated by this author are indicated under the names *G. Sedgwicki*, *G. distans*, *G. tenuis*, Portlock; *G. convolutus*, *G. sagittarius*, *G. pristis*, and *G. folium*, Hisinger; *G. scalaris*, Linn., *G. foliaceus*, Lons. (*Geol. Rep. on Londonderry, Tyrone, and Fermanagh*, pp. 317–321, pls. xix and xx.) The species described by this author as Gorgonia, probably belong to Dictyonema.

1843. W. W. Mather and E. Emmons recognized *Graptolithus dentatus* as characterizing the Utica slate. (*Geol. Rep.* 1*st Dist. N. Y.*, p. 390, *and Geol.* 2*nd Dist. N. Y.*, p. 279.)

1843. J. Hall described *Graptolithus Clintonensis*, from the shales of the Clinton group in the Upper Silurian. (*Geol. Rep.* 4*th Dist. N. Y.*, p. 72, fig. 12.)

1845. Sir R. I. Murchison, De Verneuil, and Count Keyserling enumerated *G. sagittarius*, Hisinger, and *G. distichus*, Eichwald, as characterizing the Silurian formations of Russia. (*Geol. of Russia and the Ural Mts.*, vol. ii, p. 382.)

1846. Prof. Geinitz repeats the opinion expressed by himself in 1842, regarding the nature of the graptolites; and divides them into two sections, the straight and the spiral forms. In the first section he describes four species: 1. *G. foliaceus*, Murchison, (with which he identifies *G. pristis* and *G. folium*, Hisinger, and *G. dentatus*, Vanuxem); 2. *G. priodon*, Bronn, (under which he includes *G. Ludensis*, Murchison, and *G. teretiusculus*, Hisinger); 3. *G. sagittarius* and *G. scalaris*, Linn. (which he regards as varieties of the same species), *Fucoides serra*, Brong., and *G. Murchisoni*, Beck; 4. *G. serratus*, Schlot. (*Grundriss der Verstein*, p. 310, pl. x.)

1846. E. Emmons published *Fucoides simplex* [= *Graptolithus secalinus*], from the roofing-slates of Hoosic. (*Natural History of New-York, Agriculture*, vol. i, pl. xvii, fig. 1.)

1847. J. Hall described and figured fifteen species of graptolites, mostly new, from the Lower Silurian strata, placing them among zoophytes. (*Pal. N. York*, vol. i, p. 265, pls. lxxii, lxxiii, and lxxiv.)

1848. Rev. Prof. Sedgwick announced the occurrence of *Graptolithus sagittarius*, His., and *G. latus*, McCoy, in the Skiddaw slates. (*Quarterly Jour. Geol. Soc.*, vol. iv, p. 223.)

1848. J. W. Salter described *G. folium*, *G. pristis*, Hisinger, *G. pristis*, var. *foliaceus*, Portlock, *G. ramosus*, Hall, *G. Tænia*, Sowerby and Salter, *G. tenuis*, Portlock, and *G. sextans*, Hall, from the slates of Loch Ryan, etc. (*Quart. Jour. Geol. Soc.*, vol. v, pp. 15–17.)

1848. Prof. Philips enumerated the *G. Ludensis*, *G. Murchisoni*, and

three other species in the Builth, Llandeilo, and Haverford-west districts. (*Memoirs of the Geol. Survey*, vol. ii, part 1, p. 308.)

1849. James Nicol enumerated and described *Graptolithus Griestonensis*, *G. convolutus*, *G. Ludensis*, and *G. laxus*. (*Quarterly Jour. Geol. Soc.*, vol. vi, pp. 63 and 64.)

1849. J. Hall stated the occurrence of twenty species of graptolites in the Lower Silurian rocks; two other species having been found in the Clinton formation.* (*Proceedings of the Amer. Assoc. for the Advancement of Science*, 1849, p. 351.)

1850. J. Barrande published a memoir upon the graptolites of Bohemia, describing seventeen species of *Graptolithus*, of which fifteen were new; a new genus, *Rastrites*, with four species; and the genus *Retiolites*, with one species. These are all placed among the Polypi. All of these species, except one, are found in the Upper Silurian; four of them occur in the colonies of the inferior division, and pass upward to the superior beds; while one species is restricted to the lower division. M. Barrande has given in this memoir a resumé of the geographical and geological distribution of the graptolites in the different countries of the globe.

1850. Prof. McCoy described three species of graptolites, proposing the name *Diplograpsus* for those with a double series of cellules. He proposed also the generic name *Protovirgularia* for a zoophyte which he refers to the Gorgoniadæ, but which may perhaps belong to the Graptolitidæ. (*Annals and Magazine of Nat. Hist.*, vol. vi, 2nd series, pp. 270–272.)

1850. Prof. Harkness described the graptolites found in the black shales of Dumfries-shire, recognizing two species of *Rastrites* and ten species of Graptolites. (*Quar. Jour. Geol. Soc.*, vol. vii, pp. 59–65, pl. i.)

1851. Prof. McCoy published descriptions and figures of graptolites from British palæozoic rocks, adopting the name *Diplograpsus* for the species with two ranges of cellules. Of fifteen species which he described, eleven are identified as those of preceding authors, and three of these are recognized as American species. (*British Palæozoic Fossils*, pp. 3–9, pl. 1 B.)

1851. Dr. H. A. Prout described a graptolite, *G. Hallianus* [= *Dendrograptus*], from the Potsdam sandstone of the St. Croix River. (*Am. Journal Science* [2], vol. ix, p. 187.)

1851. Edward Suess published descriptions of Bohemian graptolites, reproducing nearly all of those described by Barrande, recognizing several other known species, and describing nine new species. He proposed the name *Petalolithus* as a substitute for *Diprion*, = *Diplograptus*. (*Natur-*

* This number of twenty species included some forms known, but not at that time described.

wissenschaftliche Abhandlungen, vierter Band, pp. 88–134, pls. vii, viii, and ix.)

1851. J. W. Salter described *G. tenuis*, Portlock, and *G. bullatus*, = *G. pristis* ?, from the Silurian rocks of Scotland. (*Murchison, Silurian Rocks of Scotland, Quart. Jour. Geol. Soc.*, vol. vii, pp. 173 and 174.)

1851. Boeck; *Bemarkinger Angaaende Graptolithen Christiania* (cited by Geinitz; the work not seen by the writer).

1851. Scharenberg, *über Graptolithen* (cited by Geinitz; work not seen by the writer).

1852. Prof. Geinitz described the graptolites of Saxony, placing them among zoophytes, and proposing the genera *Monograpsus* and *Cladograpsus* for certain forms of graptolites, and the genus *Nereograpsus* to include *Myrianites*, *Nereites*, etc. He enumerates and describes fifty species of graptolites of his own, or of preceding authors; and one species of *Retiolites*, *R. Geinitzianus*. (*Die Versteinerungen der Grauwacken-formation*, heft i, *Die Graptolithen.*)

1852. J.W. Salter described some graptolites from the south of Scotland, recognizing three species. (*Quar. Jour. Geol. Soc.*, vol. viii, pp. 388–391, pl. xxi.)

1852. J. Hall reproduced the *Graptolithus Clintonensis*, and described *G. venosus*, = *Retiolites venosus*. He also described the genus *Dictyonema*, suggesting its relations with *Graptolithus*, and likewise the genus *Inocaulis*. (*Palæontology of New-York*, vol. ii, pp. 39 and 40, pl. xvii, and pp. 174–176, plates xl F, and xl G.)

1853. J. W. Salter. A new species of graptolite (*Didymograptus caduceus*, Salter), "from the Lauzon Precipice, Hudson River Group." (*Quarterly Jour. Geol. Soc.*, vol. ix, p. 87.)

1855. Dr. Emmons described several new species of Graptolites, and proposed the generic names of *Nemagrapsus*, *Glossograpsus*, and *Staurograpsus*. (*American Geology*, vol. i.)

1857. Prof. Meneghini, from collections made by General De la Marmora, described ten species of graptolites from the Silurian rocks of the Island of Sardinia, of which eight species were new. (*Palæontologie de l'Ile de Sardaigne.*)

1857. J. Hall communicated to Sir William E. Logan descriptions of twenty-one new species of graptolites from the Lower Silurian rocks of Point Lévis (Lauzon seigniory) near Quebec, (many of the species having compound forms not before known among this family of fossils,) and proposed several new genera. (*Report of Progress, Geol. Survey of Canada*, 1857. See also the *Canadian Naturalist and Geologist*, vol. iii.)

1859. J. Hall published *Notes upon the genus Graptolithus*, with an enumeration of the Canadian species; a notice of graptolite-stipes with reproductive cells, together with descriptions of two new species. (*Twelfth Report on the State Cabinet*, Albany, pp. 45 and 58, 1859.)

1859. The preceding notes were reproduced, with descriptions of five additional species of *Graptolithus*, one *Retiograptus*, the genus *Thamnograptus* with two species, and one species of *Rastrites*. (*Palæontology N. Y.*, vol. iii, pp. 495 and 522.)

1860. J. Hall, in continuation of the paper from the Twelfth Report on the State Cabinet (from *Palæontology of New-York*, vol. iii, Supp.), described additional species of *Graptolithus*, *Retiograptus*, *Thamnograptus*, and *Rastrites* as above. (*Thirteenth Report of the State Cabinet*, pp. 55–64, 1860.)

1861. J. W. Salter in "New Fossils from the Skiddaw Slates," noticed the occurrence of several species of *Graptolithus*, and the discovery of a branching form similar to those which Sir William E. Logan first brought to light in Canada, which he proposed to term *Dichograptus*. (*Geologist*, vol. i, p. 74.)

1861. Prof. McCoy sent to the writer a proof of a plate of graptolites from the "*Palæontology of Victoria*." Among the figures are species closely resembling or identical with *G. ramosus*, *G. furcatus*, and *G. gracilis;* while others resemble *G. pristis*, *G. sagittarius*, &c. The descriptions or farther illustrations have not come under our notice.

1861. E. Billings "On the occurrence of Graptolites in the base of the Lower Silurian." The paper contained a review of the work of Freidrich Schmidt, and a comparison of the graptolitic zones in Europe and America, with a view to show that the graptolite-schists of Norman's Kill near Albany are not in the upper part of the Lower Silurian division. (*Canadian Naturalist and Geologist*, vol. vi, pp. 344 and 348.)

1863. Sir William E. Logan recognized the occurrence of *Graptolithus bicornis*, *G. ramosus*, *G. mucronatus*, and *G. pristis*, characteristic species of the shales of Norman's Kill, in the Utica and Hudson River formations of Canada. (*Geology of Canada*, p. 200, and Catalogue of Fossils, p. 942. *Idem*, Graptolites of the Quebec group, pp. 226 and 228.)

1863. J. W. Salter (Note on Skiddaw-Slate Fossils) noticed some new species of graptolites, proposing the new genus *Tetragraptus*, and describing the genus *Dichograptus* previously proposed and cited above. (*Quarterly Journal of the Geological Society*, vol. xix, pp. 135–140, with illustrations.)

⁂ The *Graptolithus* from the Hoosic slate-quarries was named by Prof. Eaton *Fucoides secalinus*, and the specimens were thus labelled in the cabinet of the Rensselaer School at Albany, as known to the writer from 1832 to 1836; but we have been unable to find any published description.

CHAPTER II.

I.—SYNOPSIS OF THE SPECIES OF GRAPTOLITIDÆ OF THE QUEBEC GROUP, DESCRIBED IN THIS MEMOIR.

A. SPECIES HAVING A BILATERAL ARRANGEMENT OF PARTS. (Sub-genus *Monoprion*, Barrande; *Monograptus*, Geinitz.)

Genus GRAPTOLITHUS, Linnæus.

a. Species consisting of two stipes from a single axis. (*Didymograptus*, McCoy; *Cladograptus*, Geinitz in part.)

	Plate.	Figure.
G. nitidus	1	1– 9
patulus	1	10–15
bifidus	1	16–18
bifidus	3	9–10
indentus	1	20
extenuatus	1	21–22
constrictus	1	23–27
similis	2	1– 5
arcuatus	2	6–10
extensus	2	11–16
pennatulus	3	1– 8
pennatulus	5	9

b. Species consisting of four simple stipes from a single axis, with or without a central disc. (*Tetragraptus*, Salter. *Dichograptus*, Salter, in part.)

	Plate.	Figure.
G. bryonoides ?	3	11–12
bryonoides	4	1–11
bryonoides	6	4
denticulatus	4	12–16
quadribrachiatus	5	1– 5
quadribrachiatus	6	5– 6
fruticosus	5	6– 8
fruticosus	6	1– 3
crucifer	5	10
Headi	6	8
alatus	6	9
Bigsbyi	16	22–30

c. Species consisting of eight simple stipes proceeding from a single axis, with or without a central disc. (*Dichograptus*, Salter, in part.)

	Plate.		Figure.
G. octobrachiatus	7	....	1–7
octobrachiatus	8	....	1–4
octonarius	10	....	1, 2

d. Species consisting of more than eight simple stipes proceeding from a single axis, with a distinct broad corneous disc. (*Dichograptus*, Salter, in part.)

	Plate.		Figure.
G. Logani	9	....	1–9
Logani, var.	11	....	7

e. Species with the stipes proceeding from a single axis, and more or less frequently branched during their entire length; not known to have a central disc.

	Plate.		Figure.
G. flexilis	10	....	3–9
rigidus	11	....	1–5
abnormis	11	....	6
Richardsoni	12	....	1–8
ramulus	12	....	9,10

B. Species (so far as known) consisting of simple stipes which are celluliferous on two sides.

a. Cellules tubular, inclined to the axis, aperture subquadrangular.

	Plate.		Figure.
G. (Diplograptus) pristiniformis	13	....	15–17
" inutilis	13	....	14

b. Cellules short and square, aperture transversely-elliptical, apparently excavated in the margin of the stipe.

Genus Climacograptus, Hall.

	Plate.		Figure.
C. antennarius	13	....	11–13

Genus Retiolites, Barrande.

	Plate.		Figure.
R. ensiformis	14	....	1– 5

C. Species with numerous simple stipes from a single axis, in bilateral arrangement. (Other species known only as simple stipes.) (Sub-genus *Diprion*, Barrande; *Diplograptus*, McCoy.)

Genus Retiograptus, Hall.

	Plate.		Figure.
R. tentaculatus	14	....	6–8

D. Simple stipes with quadrilateral arrangement of parts.

Genus Phyllograptus, Hall.

	Plate.		Figure.
P. typus	15	....	1–12
ilicifolius	16	....	1–10
Anna	16	....	11–16
angustifolius	16	....	17–21

E. Species having stem-like axes with numerous irregular ramifications.

Genus Dendrograptus, Hall.

	Plate.		Figure.
D. flexuosus	17	....	1–2
flexuosus?	18	....	4
divergens	17	....	3, 4
striatus	17	....	5, 6
erectus	17	....	7
fruticosus	17	....	8, 9
diffusus	18	....	1–3
gracilis	18	....	5, 6

F. Species with flabellate or funnel-shaped fronds, the branches of which are connected by regular dissepiments giving a fenestrate structure, or by unfrequent and irregular transverse bars, and sometimes by an anastomosing of the adjacent parts of the branches.

Genus Callograptus, Hall.

	Plate.		Figure.
C. elegans	19	....	1–4
Salteri	19	....	5–8

Genus Dictyonema, Hall. (Graptopora, Salter.)

	Plate.		Figure.
D. irregularis	20	....	1, 2
robusta	20	....	3, 4
quadrangularis	20	....	5
Murrayi	20	....	6, 7

G. SPECIES CONSISTING OF BRANCHES WITH SUB-CYLINDRICAL OR ROUNDED AXES; THE ULTIMATE PINNULÆ ELONGATE, SETIFORM, OR PLUMOSE, AND ALTERNATELY ARRANGED ON THE TWO SIDES OF THE AXIS OR LARGER RAMUS.

Genus PTILOGRAPTUS, Hall.

	Plate.	Figure.
P. plumosus	21	1–4
Geinitzianus	21	5–8

Genus THAMNOGRAPTUS, Hall.

	Plate.	Figure.
Thamnograptus Anna	21	9

SPECIES INTRODUCED FROM THE UTICA SLATE OF LAKE ST. JOHN, FOR COMPARISON AND ILLUSTRATION.

GRAPTOLITHUS.

	Plate.	Figure.
G. (= Monoprion = Didymograptus) flaccidus	2	17–19
G. (= Diplograptus) quadrimucronatus	13	1–10

RETIOGRAPTUS.

	Plate.	Figure.
Retiograptus eucharis	14	9

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§ II.—DESCRIPTIONS OF THE SPECIES OF GRAPTOLITIDÆ FIGURED IN THIS MEMOIR.

GENUS GRAPTOLITHUS, Linnæus.

Generic Characters.—Polypidom or frond consisting of slender elongated stipes or stems, which are flattened and quadrangular, and may be simple or compound, and sometimes bifurcating. The cellules take their origin from a common body or canal, which is parallel to a slender axis.

Some of the species have the cellules in single series, and others have them in two series, arranged on opposite sides of the stipe.

Those species with the single series of cellules (*Monoprion,* = *Monograptus*) have the axis marginal; while those with the two series of cellules (*Diprion,* = *Diplograptus*) have each series entirely independant of the other and separated by a double solid axis, leaving no communi-

cation between the series, each of which has its common body or canal, as in those with the single series of cellules. This character is clearly shown in some of the bi-celluliferous species, which subdivide above the base by the dehiscence of the axes.

The species having a single series of cellules are developed in a bilateral arrangement of the parts on the two sides of a central point or radicle. The simplest forms known consist of two single elongate stipes; others have four, eight, or more simple stipes; while in other species the stipes are variously bifurcated; but in all they are symmetrically and bilaterally arranged upon the two sides of the specimen. Many of these compound forms have the bases of the stipes united in a central corneous disc or cup, which is of the same substance as the stipes, thickened in the middle, and attenuate at the margins, and which in the living condition was probably of a concavo-convex form.

The centre of these discs on the exterior side often presents a small prominence or point, which however does not bear evidence of having been attached, at least during the later periods of the animal's life.

The species under this genus may for convenience be distributed in two sections with several subordinate divisions, as shown on pp. 65 and 66.

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1. Graptolithus nitidus, Hall.

Plate I, figures 1–9.

(G. nitidus, Hall: *Geological Survey of Canada*, Report for 1857, page 129.)

Description.—Frond composed of two simple stipes proceeding from a small radicle, and diverging at an angle of about 175°. Stipes narrower at the base, and gradually widening towards the extremities, which in perfect specimens are somewhat rounded from the partial development of two or three of the terminal cellules. Radicle short, abruptly tapering to a slender point. The stipes in their greatest width are from six to ten hundredths of an inch, while near the base they are often not more than five hundredths of an inch in width. The proportion of the stipe occupied by the common body is about one sixth, or less than one sixth of the entire width. In the broader stipes, the limits marked by the pustuliform elevations indicate the bases of the cellules. In some specimens, one fourth of the width is occupied by the common body.

Cellules long and narrow, from thirty-two to thirty-four in the space of an inch, curving slightly upwards, nearly twice as large at the

aperture as at the base, and about three times as long as their greatest width when the stipe is flattened ; inclined to the axis at an angle of from 35° to 45° ; division-walls of cellules in contact, or united for three fourths of their entire length ; margin of the aperture straight, or slightly curved near the anterior edge, making an angle of 110° or 112° with the axis ; the anterior margin, in the broader stipes, lies over the base of the third cellule in advance. The limits of the cellules are strongly marked by a line indicating the place of the partition or divisional cell-wall, which on one side often terminates below in a pustule.

This beautiful little species differs very distinctly from all others of the genus which I have studied ; and it bears little relation to any of the European forms described, so far as they have come under my observation. The substance of the stipe is usually thickened, brownish-black in color, smooth or slightly wrinkled from desiccation, and rarely marked with distinct striæ parallel to the cell-margins. The striæ apparently indicate the successive stages of growth or development of the cell-walls. The divisions between the cellules are strongly marked by what usually appears to be a distinct groove produced by the folding of one cell over the other at the line of junction, this line indicating the place of the cell-partition. The sheath or common body of this species is usually partially filled with stony matter, and a section presents an extremely elongated oval form. This condition may be partly due to the original character of the body, or to the nature of the matrix ; which is less finely laminated than some of the graptolitic slates, but preserves the fossil in a very beautiful manner. The imprints are stained by oxide of iron, and the striæ marking the divisions of the cellules are often well preserved. The transverse striæ parallel to the apertures of the cells are often distinctly seen in casts of the interior.

The minute tubercles marking one side of the stipe are rarely shown on the two sides, and sometimes on neither side. The conditions of pressure may have had some influence in causing this appearance ; since the point of the abrupt bending of the partition between the two cellules may have resisted more than the other parts, and thus produced the prominence observed. The proportions of parts are subject to slight variations, dependent mainly on the degree of stipe-development. In the narrower forms, the cell-aperture often lies vertically above the base of the second cellule in advance, instead of above that of the third as in the wider forms. In the relations of the cellules to each other, they appear as if the pressure had been exerted obliquely to the direction of the axis ; the cellules being slightly *en échélon*. There are however many indications pointing to such an arrangement as being the original disposition of the cellules on the axis, not only in this but in other species.

The impressions of *G. bryonoides* resemble those of this species ; but

the stipes are broader, the striæ less rigid and distinct, and the tubercles and coarser denticles of *G. nitidus* are absent. In mode of growth and general aspect, this species resembles *G. serratulus* of the Hudson River group (Pal. N. Y., vol. 1, p. 274, pl. lxxiv, fig. 5 *a*, *b*); but in the latter the denticles are coarser and more oblique, the lower side being much the longer, and the stipes are more distinctly linear; while in *G. nitidus* the stipes become gradually wider from the base, and are very distinctly striate and pustulose in well-preserved specimens.

Explanations of Figures of Graptolithus nitidus, Hall.

Plate I.

1. A young individual preserving the radicle and the two stipes.
2. The extremity of a stipe enlarged, showing the partially-developed cellules.
3. A larger specimen of similar character to fig. 1, showing the pustules at the base of the cellules. The extremities are not quite entire.
4. A part of the left side of fig. 3 enlarged, showing the pustuliform elevations.
5. An enlargement from another specimen, with the cellules obliquely compressed, and the pustules obscurely shown.
6. Two smaller individuals, which, from juxtaposition, similarity of size, etc., seem as if they may have originated from a common base.
7. An impression of a more extended form, which is proportionally narrower than fig. 3.
8. A still narrower form of stipe, diverging almost rectangularly from the direction of the radicle.
9. A well-preserved small individual, enlarged three diameters.

Formation and Locality.—Shales of the Quebec group; Point Lévis.

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2. Graptolithus patulus, Hall.

Plate I, figures 10–15.

(G. patulus, Hall: *Geological Survey of Canada*, Report for 1857, page 131.)

Description.—Frond composed of two simple stipes diverging almost rectangularly from a small radicle. Stipes long, linear, widening very gradually from the base to the extremities, which are somewhat rounded from the immaturity of the later cellules. Width from base of serratures to the back of the stipe, from one sixteenth to one twelfth of an inch. Surface strongly striate in the direction of the cellules; striæ curving. Radicle minute. The proportion of the stipe occupied by the common body varies from a perceptible line to one fifth of the entire width, and is dependent partly or entirely on the direction of the pressure.

Cellules distinctly limited by the partition-walls, about from twenty-four to twenty-six in the space of an inch ; rather wide, making an angle of about 60° with the direction of the axis, and slightly curving upwards ; their proportions vary according to the width of the stipe, being from three to four times as long as wide. Outline of the aperture curved, concave, making an angle with the axis of about 130° ; on the lower or posterior side produced into mucronate points which curve gently forward : walls of the cellules distinctly striated parallel to their margins, for one half the depth. The anterior margin of each cellule is vertically above the base of the second cellule in advance.

Fragments of this species are numerous upon some slabs of greenish or blackish-green slate where other species occur. The remains of single stipes are sometimes four or five inches in length, showing in different individuals little variation in width after becoming perfectly developed, which occurs within an inch of the radicle. Sometimes the stipes are compressed vertically, and present the smooth linear base or exterior, which is less in width than when compressed laterally. The lateral faces of the stipes exhibit some variety of surface, dependent on the degree of compression, or in some instances, on the replacement or filling of the interior by iron pyrites. In these cases, or when the branch is not flattened, the surface is deeply striated or wrinkled obliquely. Sometimes when extremely compressed, the surface has an appearance of vesicular structure, which is probably due to influences attending the mineralization of the fossil, or the filling up of the original canal.

This species is palpably different from the last in the greater extent of the stipes, and in their almost perfectly linear character. The form of the denticles, and their angle with the axis, as well as their proportional distance, are distinctive characters. The *G. virgulatus* of Beck (Geinitz's Graptolithen, page 37, pl. v, fig. 36) bears some resemblance to this species in the figure of natural size ; but our species does not correspond with the enlarged figures.

Explanations of Figures of Graptolithus patulus, Hall.

Plate I.

10. A specimen preserving the radicle, and a stipe on one side two and a half inches in length.
11. The distal extremity of a larger stipe. Some of the cells are filled with iron pyrites.
12. A short stipe broken off near the radicle, showing the narrow form near the base, and a greater width beyond, exceeding that of the ordinary forms.
13. A part of fig. 12 enlarged.
14. A part still further enlarged to show the striæ parallel to the cell-apertures.
15. An enlargement from fig. 11, where some cells are filled with iron pyrites, showing their extension almost to the back of the stipe.

Formation and Locality.—Shales of the Quebec group; from loose masses below the village of Point Lévis.

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3. Graptolithus bifidus, Hall. (n. s.)

Plate I, figures 16–18; Plate III, figures 9, 10.

Description.—Frond two-stiped: stipes diverging from the small short radicle, and curving slightly inward, and thence extending in right lines including an angle of from 15° to 20°, varied by growth or accident. Stipes very narrow, rounded at the base, and gradually expanding above, attaining their greatest width at about two thirds of the distance from the base, from which they are gradually narrowed to the extremity; they curve on the celluliferous margin, and are essentially straight on the back. The cellules continuing to increase in length as the stipe is extended to the point of greatest width, give the peculiar curving outline to the celluliferous margin. In the stipes of ordinary width, about one sixth of the space is occupied by the common body; though this proportion varies with the development of the stipe. Test thin, nearly smooth, or with faint striæ parallel to the cell-margins: divisions between the cellules strongly marked, and frequently terminating below in a minute pustule. The width of stipe varies from one fifteenth of an inch at the base, to one eighth or even one fourth of an inch in the widest portions. Cellules long and slender, except a few at the base, and some partially developed near the apex: the length of the cellules is from three to four and a half times their width, according to the degree of development, and they incline to the axis at an angle of 48° near the lower part, curving more directly upwards in the middle, or more fully developed part of the stipe. Near the base of the stipe the angle of the cellules is greater, and towards the apex it is less, until the last few are inclined at a very low angle. The cellules are free for from one fourth to one third of their length. The apex is extended in a sub-mucronate point. The curving of the cell-margin forms an angle of about 120° with the axis in the widest part of well-developed stipes.

This species is very peculiar, differing from all others described in this memoir (except *G. pennatulus*) in the great inequality of width in the stipe, and the apparently continuous increase of width from the extension of the cellules; while the younger cellules near the apex seem to be slowly developed. The stipe at the base is nearly round. Of the earlier cellules usually four or five and sometimes six or seven do not attain

the full proportions. In several specimens (and indeed in all those upon which the species was originally founded), the stipes diverge from the radicle at an angle of 15° or 20° with the celluliferous faces on the inner or approximate margins. A later examination of other collections shows some specimens where the divergence is greater, and the development of parts more excessive.

Three individuals of this species from the shales at Point Lévis preserve very constant characters in the mode of growth and structural details. One, a single stipe much longer than the others from the same locality, presents some departure from the prevailing characters, and is referred with hesitation to this species. Another specimen among later collections from above the river St. Anne, has more divergent stipes and a stronger form than those first described. In the imperfect condition of preservation of these specimens, it is not easy to determine what extent of variation in individuals of this form may be due to the mode of growth and to other causes.

EXPLANATIONS OF FIGURES OF GRAPTOLITHUS BIFIDUS, Hall.

PLATE I.

16. A small specimen from the same fragment of slate with fig. 17.
17. An individual of ordinary size.
18. An enlargement of the upper part of one stipe of fig. 17.

PLATE III.

9. An individual of this species, having a greater divergence of the stipes than is usually observed.
10. An enlargement from one of the stipes of the preceding, showing the form of serratures, and the minute pustules at the base of the cell-divisions.

Formation and Localities.—Shales of the Quebec group ; Point Lévis, and three miles above the river St. Anne.

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4. GRAPTOLITHUS INDENTUS, Hall.

Plate I, figure 20.

(GRAPTOLITHUS INDENTUS, Hall : *Geological Survey of Canada*, Report for 1857, *page* 128.)

Description.—Frond consisting of two simple stipes, diverging at the base from a slender radicle, and making an angle between the two of 50° for the first quarter of an inch, and above this continuing in a nearly par-

allel direction. Test somewhat rough : width of stipe about six hundredths of an inch ; the back marked by a strong axis, and a scarcely appreciable portion occupied by the common body. Cellules narrow, distant, about twenty in the space of an inch ; each one having a length of about three times its width, half of the length being free ; inclined at an angle of about 33° to the axis : aperture at right angles to the axis ; the apex acute and pointed.

This species bears a resemblance to *G. extenuatus* in the width of stipe and proportional distance of cellules ; but the angle of inclination of the cellules and the form of aperture are quite different ; the absence of pustules at the base of the cell-divisions is also a very distinctive character. The stipes of this species bear a very close resemblance to those of *G. quadribrachiatus ;* but the individual figured, in which the base is preserved, shows in its peculiar curving and smaller serratures near the base, a feature which belongs only to the two-stiped forms. The cellules also appear to be narrower, and are slightly closer in their arrangement ; stipes of the same size of the two species, showing respectively eighteen and twenty cellules in equal spaces.

EXPLANATION OF FIGURE OF GRAPTOLITHUS INDENTUS, Hall.

PLATE I.

20. An individual of the natural size, the continuation of the stipes having been broken off.

Formation and Locality.—Shales of the Quebec group ; Point Lévis.

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5. GRAPTOLITHUS EXTENUATUS, Hall. (n. s.)

Plate I, figures 21, 22.

Description.—Stipe slender, linear, straight ; substance smooth, except the striæ indicating the cell-partitions ; width a little less than one twentieth of an inch, the common body occupying a little more than one quarter of the width. The back of the stipe is marked by a strong marginal axis. Radicle unknown.

Cellules narrow, very gradually expanding from the base, length about three and a half times the width ; making an angle with the axis of nearly 20°, and curved near the base. Apertures truncate, slightly curved towards the anterior margin, and nearly at right angles with the axis ; free for about two fifths of their length ; about twenty-four in the space of an

inch. The apex of the cell-denticle or aperture is a little forward of the tubercle marking the base of the second cell in advance. The cell-partitions or septa are not strongly marked, but distinct under a lens, and terminate below in a minute rounded process or pustule.

(The specimen on which this description is founded is a fragment of two and a half inches long. Other fragments on the same piece of weathered shale appear to be identical with it, but are too obscure for satisfactory determination. It is supposed to be a bibrachiate form.)

This species bears considerable resemblance to the figure of *G. tenuis* of Portlock, as given by McCoy (Brit. Palæozoic Fossils, pl. i. B, fig. 4 a, b); but the stipe of that one shows no pustule at the base of the cell-division. The original figures of Portlock do not however correspond so nearly with our species in its cellules, while the axis is not so strongly developed. Compared with any of the Canadian forms, except *G. extensus*, it is proportionally narrower; with that one it corresponds in the number of serratures in the same space; but the angle made by the cellules with the axis is very different, and the presence of pustules is a distinguishing feature. From all other analogous forms, this one varies in the form, proportional number, and inclination of the cellules.

EXPLANATIONS OF FIGURES OF GRAPTOLITHUS EXTENUATUS, Hall.

PLATE I.

21. A fragment of the stipe, natural size.
22. A portion of the lower extremity enlarged; a part of the specimen retaining the substance of the fossil, and a part being an impression in the slate.

Formation and Locality.—Shales of the Quebec group; Point Lévis.

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6. GRAPTOLITHUS CONSTRICTUS, Hall. (n. s.)

Plate I, figures 23–27.

Description.—Frond composed of two slender stipes, which diverge almost rectangularly from a minute radicle, or are usually bent a little backwards, a feature which is more conspicuous in young individuals. The stipes attain their full dimensions near the radicle, maintaining nearly an equal width throughout their length: the extremities are somewhat rounded from the partial development of some of the terminal cellules. The stipes in their greatest width are about nine hundredths of an inch, and vary

from five to nine hundredths in their different stages of growth and development. The common body occupies a very small proportion of the entire width, and its limits are not distinctly defined. Surface of stipes quite smooth ; test very thin, and cell-walls usually obscurely marked.

Cellules of moderate length, from twenty-four to twenty-six in the space of an inch, and inclined to the axis at an angle of about 32°, as indicated by the lines of the cell-partitions : line of the aperture truncate, or very slightly convex, making an angle of 120° with the axis, and nearly rectangular to the direction of the cellule. The cellules, in their lower part, and for two thirds of their length, are straight, and scarcely wider throughout than at their origin : at this point, just before becoming free, they are abruptly expanded on the posterior side, and this margin of the free extremity makes a larger angle with the direction of the axis. This expansion of the cellule is perhaps as properly a sudden constriction just below the orifice, or at the base of the cell-denticle. The cell-denticles, under a strong lens, are seen to be finely striated parallel to the line of the aperture.

This species in its mode of growth and general form resembles *G. patulus*, but in its development it earlier attains the full width of the stipe. It is always smoother on the exterior surface, and the cell-walls rarely make distinct striæ, as in that species, though this character is visible under a lens. The form of the denticles is however very characteristic ; and this at once distinguishes it not only from *G. patulus*, but also from every other species of this group. It is associated in the same slates with *G. patulus* and *G. quadribrachiatus*.

A specimen in the shales of Gros Maule, preserving all the essential features of this species, has apparently a thicker test, and the interior is partially filled with stony matter, so that the parts are more clearly seen. In this one the cells show a very gradual expansion towards the aperture, and a slight curvature of the cell-partitions near the base, while the constriction below the cell-mouths is more strongly pronounced.

Explanations of Figures of Graptolithus constrictus, Hall.

Plate I.

23. A young individual of the natural size.
24. An older specimen.
25. A part of a much more extended stipe, but which is not wider than fig. 23.
26. A part of a stipe from Gros Maule.
27. An enlargement showing the form of cells, the cell-denticles or apertures, and the characteristic apparent constriction.

Formation and Localities.—Shales of the Quebec group ; from some loose masses below the village of Point Lévis, and from Gros Maule.

7. Graptolithus similis, Hall. (n. s.)

Plate II, figures 1–5.

Description.—Frond consisting of two narrow sublinear elongate stipes, proceeding from a small pointed radicle, from which they diverge almost rectangularly: stipe acquiring its full width near the radicle, having a short space near the base without cellules; extremities somewhat rounded, from the partial development of the cellules. The stipe varies from five to ten hundredths of an inch in width: the cell-partitions, when visible, extend nearly to the back of the stipe, leaving a narrow space occupied by the common body. Surface nearly smooth: cell-partitions seldom seen, and not distinctly visible; the specimens extremely compressed.

Cellules somewhat short and broad, little curved, about twenty-one in the space of an inch, inclined at an angle of 23° to the axis. The cellules are from two to three times longer than wide, this depending on the width of stipe: margin of aperture truncate, making an angle with the axis of from 118° to 130°; the cell-walls show obscure striæ parallel to the aperture. The apex of the denticle is vertically above the posterior basal edge of the second cellule in advance.

The nearest affinities of this with any American species are with those designated by me as *G. sagittarius* and *G. serratulus* from the shales at Norman's Kill, near Albany; but the cellules make a much less angle with the axis of the stipe, and the whole body is less robust than the larger specimens of *G. sagittarius*. It bears a remote resemblance to the figures of *G. nuntius* of Barrande, as given both by Barrande and Geinitz; approaching more nearly to the figures of *G. sagittarius* of Hisinger, as given by Geinitz, than to any of the others; though these figures give a higher angle between the axis and the direction of the cellules. The angle made by the cellules of *G. nuntius* with the axis, as given by Barrande, is 45°, which corresponds with our Norman's Kill specimens; but they differ in other respects. The present species differs from most of the other Canadian species in the straightness of its stipe; and in the low angle made by the cellules, from all others, except *G. indentus*.

The specimens are replaced by pyrites in a dark or nearly black slate, and associated with other forms too imperfect to be identified; one of them resembling *G. quadribrachiatus*, and another *G. bryonoides*.

Explanations of Figures of Graptolithus similis, Hall.

Plate II.

1. A very young individual of this species.
2. An individual somewhat more matured.
3. An enlargement showing the form of the radicle, and the cells near their origin, with a non-celluliferous space between.
4. A fragment of a longer stipe, which is imperfect at both extremities.
5. An enlargement of fig. 4.

Formation and Locality.—Shales of the Quebec group; three miles above the river St. Anne.

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8. Graptolithus arcuatus, Hall. (n. s.)

Plate II, figures 6–10.

Description.—Frond consisting of two simple widely divergent stipes proceeding from a small radicle, and bent backwards or downwards, making on the upper side nearly or more than a right angle with the direction of this radicle, and then curved gently upwards; presenting a broadly arcuate stipe gradually expanding in width from the base to the extremity, and celluliferous throughout its entire length. A single denticle, or similar process, appears above the rootlet. Radicle short, obtusely pointed. The stipe is from four to ten hundredths of an inch in width. The cellules reach nearly to the back of the stipe, leaving a narrow space to be occupied by the common body. Test extremely compressed in the specimens examined, and towards the extremity of the cellules almost transparent. The whole has a white or silvery lustre (probably due to iron pyrites), and no lines or striæ are visible except those marking the separation of the cellules.

Cellules narrow and very little expanded towards the aperture, about twenty in the space of an inch, slightly curving upwards, and inclined to the axis at an angle of about 30°, varying a little with the curvature and development of the stipe; from three and a half to four times as long as broad. Cell-apertures slightly curved, nearly vertical towards the posterior side and arching towards the anterior side. The apex of the denticle, or posterior side of the aperture, is vertically above the base of the third cellule in advance of it.

In some specimens the radicle is broken off, and there is a process on the opposite side, giving the appearance of a radicle on the celluliferous

side of the specimen, as if the cellules had been turned downwards; but this appearance is fallacious. In examples where the radicle is broken from the margin of the stipe, the question is suggested whether it may have been a quadribrachiate species; but the pointed radicle in others is opposed to the supposition. In the specimens from which this description is drawn, there are several examples of two individuals lying with the celluliferous margins nearly or quite in juxtaposition; while the stipes crossing each other at a distant point may give an erroneous impression regarding their mode of growth.

On a cursory examination of the specimens before us, this species is readily identified by the peculiar curving of the stipes; differing in this respect from all the bibrachiate forms which have been observed. In the form of the denticles, or free portions of the cellules, this species approaches *G. patulus;* but these parts are less mucronate, and the angle between the axis and the cellules in that species is much greater, and the cellules are narrower. The general form of stipe, except in its peculiar curvature, does not differ essentially from some others previously described; but a comparison of the form of the cellules, their proportionate dimensions, and angle of inclination, will suffice to show its distinctive character.

EXPLANATIONS OF FIGURES OF GRAPTOLITHUS ARCUATUS, Hall.

PLATE II.

6. A stipe of a small individual, more than usually curved.
7. A stipe having a process just above and opposite the radicle.
8. A larger stipe, the cellules very clearly preserved.
9. A specimen showing the stipes on both sides of the radicle, and preserving their peculiar curvature very perfectly.
10. An enlargement of a portion of one of the stipes.

Formation and Locality.—Shales of the Quebec group; Point Lévis.

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9. GRAPTOLITHUS EXTENSUS, Hall.

Plate II, figures 11–16.

(G. EXTENSUS, Hall: *Geological Survey of Canada*, Report for 1857, *page* 132.)

Description.—Frond consisting of two simple linear very slender stipes, which diverge at right angles to the direction of the minute radicle, and lie in the same plane. Stipe near the radicle one fiftieth of an inch in diameter, and at a distance of four inches from the radicle, one tenth of

an inch in diameter. Fragments of single stipes have been observed, having a length of six or seven inches, with a width not exceeding that given above. Surface usually smooth; the striæ formed by the cell-partitions sometimes visible ; the back of the stipe somewhat thickened, and about one fourth of the width occupied by the common body.

Cellules short and comparatively broad, very slightly curved ; about twenty-four in the space of an inch, and making with the axis an angle of about 40°. Margins of the aperture truncate, making an angle of 98° with the axis : one third or more of the cellule is free ; and near the radicle, one half of the length of the cellule is free. The partitions are distinctly visible in well-preserved specimens ; but in most instances they are obscure.

In this collection, the specimens are mostly upon weathered surfaces of the slate ; the substance is often partially removed, and no good impressions are preserved. This species is most nearly allied to *G. similis*, but is always more slender near the base : the serratures are more distinct in smaller stipes, and the angle of the cellules with the axis is much greater ; while the angle formed by the cell-aperture with the axis is much less than in that one. It differs equally from the allied European forms, in some respects approaching the *G. sagittarius* as represented by Geinitz (Graptolithen, etc., pl. ii, fig. 4) ; but it has more the aspect of *G. Nilssoni* (fig. 17 of same plate). It differs essentially however from *G. Nilssoni* as represented by Barrande (Graptolites de Bohème, pl. ii, figs. 16 and 17), and from the figs. 19 and 31 of Geinitz, which our species never approaches in any stage of growth. In our specimens we see the connexion of the stipes with the radicle, and trace them continuously for four or five inches ; and in separated fragments, we have specimens six or seven inches long. None of these offer an approximation in variations of form and proportional distance of cellules, to those represented by Geinitz as different phases of *G. Nilssoni*. We may add, that if such differences exist in the same species, we have then no means of fixing the limits of specific variation, or of determining the species among graptolites of this character, from the separated fragments. The comparatively large number of specimens in the Canadian collection affords good means of specific determination for many of the forms ; and unless we could find upon the same stipe, evidences of such variation, we should hesitate to consider the different varieties as one species.

The *G. Nilssoni*, as figured by Harkness (Quart. Jour. Geol. Soc., vol. vii, p. 62, pl. i), differs from our species, and more nearly resembles the figures of Barrande.

EXPLANATIONS OF FIGURES OF GRAPTOLITHUS EXTENSUS, Hall.

PLATE II.

11. A single stipe more than four inches long, with the radicle and part of the opposite stipe.
12. A fragment showing a part of the stipe on each side of the radicle, natural size.
13. The radicle and adjacent cellules, enlarged from fig. 12.
14. An enlargement of fig. 12 at a point about two inches from the radicle.
15. A fragment of a stipe where the cellules are distended by iron pyrites. This fragment may belong to a different species.
16. An enlargement from fig. 15.

Formation and Locality.—Shales of the Quebec group ; Point Lévis.

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10. GRAPTOLITHUS PENNATULUS, Hall. (n. s.)

Plate III, figures 1–8 ; and Plate V, figure 9.

Description.—Frond consisting of two stipes, which diverge rectangularly, or are more or less ascending from a small radicle. Stipes narrow at the base, gradually or rapidly increasing in width for about two thirds of their length. At the base they measure not more than three or four hundredths of an inch, and increase to one tenth of an inch in the narrower individuals ; while the widest observed is three tenths of an inch at one third of the length from the base, beyond which point it is somewhat narrower. They are all more or less contracted towards the distal extremity, curved on the celluliferous side, and nearly straight on the back : the terminal cellules are developed in a line nearly parallel with the axis. The proportion of the stipe occupied by the common body is from one seventh to one fourth of the entire width. The test is apparently smooth ; that of the back of the stipe and partitions of the cells seems to be considerably thicker than the outer walls of the cellules.

The cellules, when fully developed, are long, narrow, and curved upwards, making an angle with the axis of from 30° to 45° in different individuals at the base of the cellules, and as high as 70° on the outer part of some of them ; while the average angle, taking a line from the base to the point of the cellule, is from 50° to 57°. The line of the aperture is curved : the pellicle forming the cell-walls extends along the posterior side of the cell-partition next in advance, the line of aperture making an angle with the axis of from 110° to 120° ; while the extremity of the denticle is mucronate. The fully-developed cellules have a length of eight times

their width; and in the narrower stipes, the length of the cellule is about five times the width. There are from twenty-four to thirty-two cellules in the space of an inch: (the specimen having thirty-two in an inch is a young individual, in which the cellules are more crowded, and not fully developed.) The apex of the denticle is vertically above the base of the fourth or fifth cellule in advance, varying in the narrower stipes to the third cellule in advance.

This species differs from all the others described, except *G. bifidus;* and this it very much resembles in the young individuals. There is an absence of pustules at the base of the cell-partitions, with a greater thickening of these partitions, and the denticles are usually more mucronate. If uniformity in the divergence of the stipes can be relied upon, this character will aid in distinguishing the species; but this feature may vary from accident, as in one specimen figured, which appears to have been broken in one of the stipes. This species is remarkable for the great development in the width of the stipes, which, in their extremely compressed condition, have the appearance of feathers imbedded in the shale.

The specimens from which these figures have been drawn, present the fossil in a very unsatisfactory condition; and farther collections may show the necessity of separating some of the narrower forms under another specific designation.

EXPLANATIONS OF FIGURES OF GRAPTOLITHUS PENNATULUS, Hall.

PLATE III.

1. A young specimen with the minute radicle, the stipes diverging almost horizontally, or rectangularly to the radicle.
2. A young specimen with one stipe entire, and a part of the other, less divergent than fig. 1.
3. A single imperfect stipe of a young or half-grown individual, which is narrower than usual.
4. A larger stipe, which is entire from the base to the apex.
5. A large or full-grown single stipe, which is nearly entire.
6. An enlargement to three diameters from fig. 4, showing the form and proportion of the cellules, and cell-denticles.
7. An enlargement to the same degree as the preceding, from fig. 5.
8. A young specimen where the stipes are twisted near the base, giving an appearance as if the serrations were on the outer or lower side in relation to the direction of the radicle.

PLATE V.

9. A single stipe of this species? The specimen is a large stipe, somewhat obscurely preserved upon the surface of a slab of slate, with *G. extensus*, *G. bryonoides*, and *Phyllograptus ilicifolius*. It is from the same locality with *G. bifidus* at Point Lévis. In the form of the stipe, and its gradual diminution towards the distal extremity, as well as in the absence of visible pustules at the base of the cellules, it has the habit of *G. pennatulus*. Being the only individual observed from this locality, and the resemblance to *G. bifidus* being very close, I have referred it with much hesitation to *G. pennatulus*.

Formation and Localities.—Shales of the Quebec group; three miles above river St. Anne, and at Point Lévis.

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11. Graptolithus bryonoides,* Hall.

Plate IV, figures 1–11; Pl. III, figs. 11, 12 (?); Pl. VI, fig. 4 (?).

(G. bryonoides, Hall: *Geological Survey of Canada*, Report for 1857, page 126. *Fucoides serra*, Brongniart, *Végétaux Fossiles*, vol. i, page 71, 1828.)

Description.—Frond consisting of four simple stipes, united in pairs at their bases, and connected by a short funicle of variable length, from the centre of which proceeds a minute pointed radicle. The stipes diverge at various angles (dependent probably on distortion from pressure); narrow at their origin, and abruptly expanding above, they acquire their full width within the distance of three or four cellules, and maintain the same throughout their length to near the distal extremity, which is somewhat abruptly rounded and occupied by the partially-developed cellules. The full width of the stipes in young individuals is often not more than one twelfth of an inch, and in mature specimens about one seventh of an inch; the base having a diameter of not more than two or three hundredths of an inch. The common body occupies a very narrow space, and the solid axis is strongly defined in the flattened specimens. The substance of the stipe or pellicle is quite thin and apparently smooth, the only markings visible being the oblique striæ made by the cell-partitions.

Cellules elongate, of medium width, somewhat curved, and in the fully-developed condition about four times as long as wide, making an angle of from 40° to 50° with the axis; free for about one fourth of their length; about from twenty to twenty-four in the space of an inch, varying in different individuals and in different stages of growth. Aperture curved, making an angle of about 110° with the axis; the cell-denticles pointed,

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* I have little doubt that this species is identical with *Fucoides serra* of Brongniart (Vég. Fossiles, p. 70, 1828). The locality of that species is "*Pointe Levi prés Quebec,*" which is the same with that of *G. bryonoides*: and the figures of Brongniart correspond with figs. 9 and 10 of plate 4 of this memoir. The *Fucoides dentatus* of the same author is also probably identical with *G. pristiniformis* of this memoir, being from the same locality. It is only since these descriptions have been in print, and published references made to them, that I have discovered this identity, or I would have proposed to substitute the specific names of Brongniart for those given by me in 1857. I take the first opportunity of making the correction.

and slightly curved forward: cell-partitions usually well marked, and near the base, making a much less angle with the axis than towards the aperture.

When the funicle is broken, this species sometimes occurs like the bi-brachiate forms, as in fig. 5 of plate iv, and in that condition bears some resemblance to *G. nitidus*; but its stipes are wider, its habit more robust, the cellulės more curved, making a greater angle with the axis; the denticles coarser and more equilateral, and usually mucronate or sub-mucronate. No pustules at the base of the cell-partitions, as in *G. nitidus*, have been observed in this species. There is also a resemblance between *G. patulus* and this species; but in that one the stipes are usually more slender, the denticles more mucronate, the curve of the aperture much greater, and the cells make a much greater angle with the axis.

This species is associated in the same shales with *G. nitidus*, *G. extensus*, *G. constrictus*, and *Phyllograptus ilicifolius*. I have united with this species the specimen represented in figs. 9 and 10, of plate iv, though it presents variations in some of its characters. A small portion of one of the stipes near the base of this shows a number of cellules or serratures equal to twenty-six in the space of an inch. Its affinities are more nearly with *G. bryonoides* than with any other; and having but this individual, I refer it for the present to that species.

Explanations of Figures of Graptolithus bryonoides, Hall.

Plate IV.

1, 2, 3. Young individuals of this species.
4. An older individual.
5. A young specimen preserving two of the stipes, the funicle having been broken.
6. An enlargement from fig. 1, showing the radicle, funicle, and origin of the four stipes, with a few of the earlier cellules.
7. An older and larger specimen.
8 An enlargement showing the character and proportions of the cellules.
9. A small individual, preserving the four stipes in part, which are somewhat more slender than the usual forms of this species.
10. An enlargement of the base of the specimen, showing the cell-denticles on one of the stipes, and a proportionally longer funicle than in fig. 8.
11. An extremely elongated stipe, the lower end showing the commencement of growth; the distal extremity is broken.

Plate III.

11. A fragment of a stipe from the rough shales, with *Phyllograptus ilicifolius*. In the character of the cell-denticles it resembles the specimen pl. iv, fig. 9, and with that one may constitute a distinct species.
12. An enlargement of a part of the specimen fig. 11.

PLATE VI.

4. A frond in which three of the stipes, and the base of the fourth, are preserved. The specimen shows some peculiarity in the union of the parts by the slender funicle.

Formation and Localities.—Shales of the Quebec group ; Point Lévis, Grôs Maule, and river St. Anne.

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12. GRAPTOLITHUS BIGSBYI, Hall.

Plate XVI, figures 22–30.

(PHYLLOGRAPTUS SIMILIS, Hall : *Geological Survey of Canada*, Report for 1857, page 140. Compare *Didymograptus caduceus*, Salter : *Quarterly Journal of the Geol. Society*, vol. ix, p. 87.)

Description.—Frond broadly oval or sub-oval, consisting of four somewhat semi-elliptical stipes, which are nearly straight or slightly curved on the non-celluliferous margin, and broadly curved on the celluliferous side ; all closely united at the base in a radicle (?), and from which they are abruptly recurved. These stipes are more frequently distinct at the apex, while in some individuals they are in contact or apparently united at that point, but always separated in the centre for a distance of three fourths their length. Entire length of specimens from four to six tenths of an inch, and width three tenths of an inch, exclusive of the denticles. The individual stipes, in the centre of their length, are twelve hundredths of an inch wide. Radicle undetermined. Cellules from thirty-two to thirty-six in the space of an inch, narrow at the base, gradually ascending and curving outwards, except those near the base, which are recurved : cell-margins curved, and extended in mucronate points, which are the continuation of the cell-partitions. Test thin and smooth, with the exception of the cell-partitions.

This species presents a great variety of aspects, and the most critical examination has left some doubt as to its original mode of growth. The more perfect specimens are broadly oval, the diameters about as three to four ; and where the stipes are apparently conjoined, at the two extremities, there is a vacant space in the centre (extending about three fourths of the length, and from six to eight hundredths of an inch in width), except that some portions of one or both the other stipes are visible. In one or two individuals, there is a linear body extending longitudinally through this space, which may have been originally the axis ; but its relations cannot

be determined. Examinations have failed to exhibit any satisfactory evidences of the existence of a radicle. In most of the specimens the stipes are united at one extremity and free at the other; while their curvature is such, that if continued, they would meet. In these specimens the four stipes are often distinctly seen, two usually showing the non-celluliferous margins; while sometimes three, and rarely the four stipes show the celluliferous margins.

The individuals are extremely numerous, but in almost all instances the characters are more or less obscured by the stipes being slightly separated by intervening laminæ of slate, or by the weathering of the surface. On a single piece of slate of about a foot long by six inches wide, there are more than one hundred individuals; but nearly all of these are so obscured by weathering, that they afford little means of determining the characters or mode of growth. In the whole collection, there are not more than one or two species of which the individuals are more numerous than of this, and in no other are the characters so indistinct.

From the deep curving cellules and broad stipes, which are often apparently conjoined at the apex, I have supposed that they may, at some period of growth, have been joined along the non-celluliferous side for the entire length. On this account, I had originally referred the species to the genus *Phyllograptus*.

In some of the specimens, where two of the stipes are spreading, and show the celluliferous margins, the non-celluliferous face of a third stipe often stands vertically between them, like a stem. These forms resemble the *Graptolithus caduceus* of Salter, which was obtained by Dr. Bigsby from "the Lauzon Precipice,"* and I have hesitated in regard to making of these a new species. The name of *Phyllograptus similis* was applied to such forms as figs. 26, 29, and 30; but when it became apparent that all the other varieties of form must be referred to the same, it was necessary to remove it from that genus; and since I had already named another species *Graptolithus similis*, I take great pleasure in dedicating this to Dr. J. J. Bigsby, who early explored the geology of the northern portion of our continent, and who, in later years, has never ceased to interest himself in American geology, and to aid in its progress.

Explanations of Figures of Graptolithus Bigsbyi, Hall.

Plate XVI.

22, 23, and 24 illustrate a common condition of this species, where two of the divisions show the lateral faces, while the non-celluliferous edge of a

* This locality is probably the same with that which has furnished the greater part of the graptolites here described; the precipitous heights of Point Lévis being in the seigniory of Lauzon.

third division is seen lying nearly vertically in relation to these. The fourth division has been broken off in the separated film of slate.

25. A specimen showing the lateral faces of two divisions. Below these, in the shale, are seen the non-celluliferous edges of the two other divisions.

29 and 30 show a still closer arrangement of the parts, and the contiguity of the non-celluliferous edges at the apices, which are scarcely perceptibly separated in the shale.

26. An individual where the apices of the divisions are in contact, either conjoined, or accidentally so placed, with a narrow space in the centre. In obscure specimens it is difficult to separate such forms from *Phyllograptus*.

27. An individual where the divisions are equally spreading: one of them preserving only the base of the stipe.

28. The same enlarged.

Formation and Locality.—Shales of the Quebec group; Point Lévis.

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13. Graptolithus denticulatus, Hall.

Plate IV, figures 12–16.

(G. denticulatus: *Geological Survey of Canada*, Report for 1857, page 132.)

Description.—Frond consisting of four simple stipes proceeding from a simple radicle. Stipes slightly ascending at their origin, but immediately and strongly recurved, again bending gently upwards from the middle towards the extremities; slender at the origin, and gradually expanding to a width of from nine to twelve hundredths of an inch (exclusive of the denticles), which it almost uniformly maintains. Substance of the stipe extremely thin, and marked on each margin by a linear filiform ridge, like the ordinary solid axes of these bodies. In the impressions left on the removal of the substance, each margin shows a continuous filiform groove in the place of the thickened or solid margin of the stipe; the groove on the celluliferous or denticulate side being much stronger than that on the back of the stipe. Surface apparently smooth throughout. Cellules consisting of small mucronate equilateral denticles, placed vertically on the margin of the stipe, and rising immediately from the thickened solid edge: denticles spreading below, slightly curving, and united at their bases by a thin pellicle; varying in their distance on different parts of the stipe, and apparently in different stages of growth; sometimes twenty-four in the space of an inch, near their origin, while elsewhere the average number is from eighteen to twenty; the lower number marking the strongest stipes measured.

This species is very peculiar, differing not only from the associated species, but from all others in the arrangement of its denticles.

The specimen originally described under this name is a fragment (pl. iv, fig. 14), consisting mainly of an imprint in the shale, the substance of the fossil being preserved in some parts. The solid axis on the denticulate margin is clearly defined in the impression, and in some places the substance remains, and is expanded at each denticle on the upper side so as to occupy the base of each depression. The cellules terminate in so minute a point that no aperture is visible; but in a longitudinal division of some of them, they appear to have been hollow tubes. The back of the stipe is clearly marked (as is usual in the graptolites) by the presence of a distinct solid axis, which in no respect differs from the ridge on the opposite margin, except that the latter extends into the base of the cellules.

A further study of the collection has shown that some obscure imprints in weathered shale are of the same species. These imprints, at a few points, retain portions of the pellicle, and the form of the cellules is well preserved; they reveal moreover the mode of growth, as shown in figs. 12 and 13 of pl. iv; thus indicating their relation in this respect to *G. bryonoides* and *G. quadribrachiatus*. The recurved position of the stipes is a feature of *G. bryonoides*, but less extreme than in this one. This species may be readily identified by the pointed cellules, vertical to the axis, which *appear* to be entirely separated from the common body, except in well-preserved portions, where in a few examples they are shown to be connected at the base by a continuation of the cell-wall above the solid axis.

Explanations of Figures of Graptolithus denticulatus, Hall.

Plate IV.

12. A small imperfect specimen, preserving three of the stipes.
13. A larger and more nearly entire specimen, showing the four stipes. Their junction at the base is not quite satisfactorily shown.
14. A part of a single stipe, in which the cellules are well shown on one part; while they are compressed and nearly obliterated on the left of the curve.
15. An impresssion of a part of a stipe which is nearly straight; the imprint of the axes or thickened margins is not defined.
16. An enlargement from figure 14, showing the form of the cell-denticles, and the strong marginal axes; one portion represented with the substance remaining, and the other as an imprint.

Formation and Locality.—Shales of the Quebec group; Point Lévis.

14. Graptolithus fruticosus, Hall.

Plate V, figures 6–8; and Plate VI, figures 1–3.

(G. fruticosus: *Geological Survey of Canada*, Report for 1857, page 128.)

Description.—Frond consisting of two pairs of ascending and slightly curved stipes arising from the two sides of a long slender radicle, which is divided above: the stipes are celluliferous on the inner or adjacent margins, little divergent at the bifurcation, and continuing for a half or two thirds of their length nearly straight; above this they curve gently outwards, presenting, when not distorted, a very beautiful and symmetrical form. The stipes gradually increase in width from their origin, being at the base one fiftieth of an inch, and in the widest part one twelfth of an inch, exclusive of the denticle. The proportion of the stipe occupied by the common body is extremely narrow.

Surface smooth, or with scarcely visible striæ at the lines of the cell-partitions: axis very slender; test thin and fragile. Radicle half an inch in length. Cellules short and broad, making an angle with the axis of about 38°; the length from two to three times the diameter, and free from a third to a half of the entire length, according to their development; variably curving in different parts of the stipe. Aperture wide, apex pointed, scarcely mucronate, and sometimes acutely rounded. About fifteen cellules in the space of an inch, varying slightly in different parts of the stipe: near the base the serrature or length of the denticle is equal to the width of the stipe, while in the wider portions it is less than half the width of the stipe.

This species, in all the examples that have been observed, is a very distinct and easily recognized form. Wherever the radicle is preserved, it is longer than in any of the other species: this part bifurcates above, and the divisions, moderately diverging, represent what I have termed the funicle in the quadribrachiate forms; from each extremity of this, the stipes originate. All the divisions are little divergent, and the frond grows upwards like a small shrub. The form of the cellules differs from other species here described, except perhaps *G. indentus*, which is readily distinguished in its mode of growth, as well as by other characteristics.

Explanations of Figures of Graptolithus fruticosus, Hall.

Plate V.

6. A small individual with the radicle and extremities of the stipes broken off.
7. An enlargement from fig. 6. The serratures are either imperfect or shrunken, and do not present the characters seen in better-preserved specimens.
8. An individual nearly entire, but badly preserved in the outline of its parts.

PLATE VI.

1. A fragment showing two of the stipes entire, and the bases of two others; the radicle extending to the margin of the specimen.
2. A specimen preserving three of the stipes, one of them entire, and showing some irregularities in the bifurcation where the one is broken off.
3. An enlargement of the right-hand stipe of the specimen fig. 1.

Formation and Localities.—Shales of the Quebec group; at the upper end of Orleans Island, and three miles above river St. Anne.

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15. GRAPTOLITHUS QUADRIBRACHIATUS, Hall.

Plate V, figures 1–5; and Plate VI, figures 5, 6.

(G. QUADRIBRACHIATUS, Hall: *Geological Survey of Canada*, Report for 1857, page 125.)

Description.—Frond composed of four simple undivided stipes arranged bilaterally, or two proceeding from each extremity of the funicle. Stipes slender, very gradually increasing in width from their origin, as far as traced; usually straight, sometimes slightly curved; width from two to four hundredths of an inch at the base, and in the most perfect examples, nine hundredths of an inch at the widest part. The back of the stipe is marked by a filiform axis, and there is scarcely more space occupied by the common body. Test thin, though well preserved in the finer shales. Surface of cell-walls distinctly striated parallel to the apertures, and the cell-partitions visible nearly to the back of the stipe.

Cellules narrow, scarcely curving, and slightly expanding towards the aperture, making an angle with the axis of about 38°; the length equal to about four diameters, the free portion being from one third to two fifths their entire length. The margin of the aperture is nearly straight, or very slightly curved, making an angle of from 95° to 100° with the axis. The number of cellules in the space of an inch is from twenty-two to twenty-four, dependent on the distance from the origin of the stipe, and on the degree of development. The apex of the denticle, or posterior point of the aperture, is a little below the base of the second cellule in advance. Cell-partitions thin, and usually not well preserved.

This species, when entire, is readily distinguished from *G. bryonoides* by its straight and more slender branches, and by the general aspect and expression of the fossil; it has only a remote similarity with the other quadribrachiate forms. In separated or double stipes it bears some

resemblance to *G. arcuatus*, except that it is less curved, and the form of the cellules is distinctive. From the other bibrachiate forms, it is very readily distinguished on comparing the form of the cellules.

I had heretofore regarded this species as possessing a disc, like *G. crucifer* and others ; but on examination of all the specimens which can be satisfactorily identified with it, not one has shown a disc. The discs with four stipes, which are broken off so close that no serratures are visible, cannot be satisfactorily identified with this or any other species, and are therefore left in doubt at this time. They may be regarded as belonging to *G. crucifer*, or to the young of *G. Headi*.

EXPLANATIONS OF FIGURES OF GRAPTOLITHUS QUADRIBRACHIATUS, Hall.

PLATE V.

1. A large specimen with stipes vertically compressed.
2. A young specimen in which one of the stipes appears to be subdivided.
3. An individual with stipes a little curved, the back of the stipe visible, and showing no serratures.
4. A frond with one of the stipes broken off; one showing the cellules and distinct striæ parallel to the cell-partitions, while the other two are turned so as to obscure the cellules.
5. An enlargement from fig. 1 : the stipe has been vertically compressed, causing the cellules to show a less angle with the stipe than in the normal condition.

PLATE VI.

5. A frond preserving one stipe partially entire, and others broken off: the funicle and radicle-point are well preserved.
6. An enlargement from the specimen fig. 5, showing the form and proportion of cellules in their more perfect preservation, with the striæ parallel to the cell-margins well preserved.

Formation and Locality.—Shales of the Quebec group; Point Lévis.

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16. GRAPTOLITHUS CRUCIFER, Hall.

Plate V, figure 10.

(G. CRUCIFER : *Geological Survey of Canada*, Report for 1857, page 125.)

Description.—Frond composed of four simple, strong stipes, united at their base by a small thickened disc. Stipes strong at the base ; the two pairs connected by a short funicle, which is without a visible radicle.

The specimen lies with the celluliferous face downwards, and the stipes near their origin present only the back, which shows them to be strong, and of considerable substance, and measuring at that point five hundredths of an inch in width. Extending from the disc, the stipes are gradually turned on one side, and in their greatest width measure seventeen hundredths of an inch in diameter, including the denticles. Cell-denticles sub-mucronate, rising above the margin almost vertically; about twenty-two in the space of an inch.

This species preserves the general form of *G. quadribrachiatus*; but is more robust, and the stipes are united in a central disc. The specimen is upon a weathered surface, and very obscure; the characters being drawn from the general form and proportions. The cell-denticles are visible on a part of three of the stipes, but we are unable to trace the direction or existence of any cell-partitions. The denticles in their prominence resemble those of *G. denticulatus;* and broad stipes of *G. bifidus* have likewise some analogy with this species; but as our only specimen is imperfect, no minute comparisons can be made. It is a smaller species than *G. Headi*, but with a comparatively broader stipe, and more erect cell-denticles. In *G. crucifer* the disc is quadrilateral, with concave sides, and is somewhat oblong; while in *G. Headi* the disc is larger and essentially square, the margins being very nearly straight.

In the specimen described, the disc is without markings, as are also some other discs which may belong to this species; while a single specimen shows concentric striæ parallel to the margins.

EXPLANATIONS OF FIGURES OF GRAPTOLITHUS CRUCIFER, Hall.

PLATE V.

10. View of the specimen from which the description is drawn.
13. The disc of a young individual probably of this species.

Formation and Locality.—Shales of the Quebec group; Point Lévis.

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17. GRAPTOLITHUS ALATUS, Hall.

Plate VI, figure 9.

(G. ALATUS: *Geological Survey of Canada*, Report for 1857, page 127.)

Description.—Frond consisting of four stipes (probably simple); their bases united in a thickened disc, the central portion of which is about seven tenths of an inch in extent, and uniting to the stipes continues along their

margins for an inch and a quarter, giving an extremely alate appearance. Stipes strong, angular on the back or non-celluliferous margin: test thick: cellules unknown.

The only specimen known consists of the disc and parts of three of the stipes; the longest one extending a little beyond the limits of the disc, or so far that the alation produced by the disc is not distinguishable. The lower or non-celluliferous side is presented to view, and we know nothing of the extension of the stipes, nor of the cellules. It is probably one of the simple-stiped species, and of rare occurrence, since no other specimens are known which can be identified with it.

Explanation of Figure of Graptolithus alatus, Hall.

Plate VI.

9. The specimen represented as it occurs on a fragment of slate. The back of the stipes shows faint indentations, but they are made too strong in the engraving.

Formation and Locality.—Limestone of the Quebec group; Point Lévis.

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18. Graptolithus Headi, Hall.

Plate VI, figure 8.

(G. Headi, Hall: *Geological Survey of Canada*, Report for 1857, page 127.)

Description.—Frond robust, four-stiped; the stipes in pairs, joined by a short funicle at the base, and united in a broad thickened quadrangular disc. Stipes strong, somewhat alate near the base from the extension of the substance of the disc for a short distance along their margins, extremely elongate, and extending in a nearly direct line towards their extremities; celluliferous on one side. The width in a transverse direction, at the junction with the disc, is six hundredths of an inch; and in the widest portion, fourteen hundredths of an inch. Disc quadrangular, nearly square, slightly extended along the stipes, with straight margins in the spaces between; measuring in the specimen examined, one inch and one eighth in each diameter across the centre.

Cellules elongate, distinctly curved, making with the axis an angle of about 50°; length four or from four to five times the diameter at the aperture: denticles sub-mucronate, sub-erect, about twenty-four in the space of an inch. The margin of the aperture is apparently curved; its

angle with the axis cannot be satisfactorily determined from the specimen. Cell-partitions strong.

The specimen from which this description is drawn, consists of the disc and a part of two stipes, the other two being broken off just beyond the disc; one of the stipes measures nearly seven inches from the centre. When the disc is preserved, this species can be readily distinguished. Separated stipes bear a near resemblance to *G. bryonoides*; but the abrupt, narrowing at the base of the stipes, and the shorter denticles, characterize *G. bryonoides*. In the specimen described, we have little more than an impression of the stipe, and this is in a coarse material; so that there still remains some obscurity regarding the surface of the test, and the exact form of the cellules and their apertures.

EXPLANATION OF FIGURE OF GRAPTOLITHUS HEADI, Hall.

PLATE VI.

8. A representation of the specimen of the natural size, and as it occurs on the surface of the stone. (The upper separated portion of the stipe is placed a little lower in the figure than it is on the stone, in order to bring it within the dimensions of the plate.)

Formation and Locality.—Shales of the Quebec group; Point Lévis.

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19. GRAPTOLITHUS OCTONARIUS, Hall.

Plate X, figures 1, 2.

(G. OCTONARIUS, Hall: *Geological Survey of Canada*, Report for 1857, page 124.)

Description.—Frond consisting of eight stipes uniting in pairs at the base, and each pair again united in a similar manner, making one half the frond; the two parts are joined by a funicle, in the centre of which is a small rootlet. The two sides are equal and symmetrical, giving a bilateral arrangment to the whole. Stipes narrow and rounded at the base, having a diameter of from two to four hundredths of an inch below the bifurcations; in the figured specimen, at a distance of from one half to three fourths of an inch from the base, they are eleven hundredths of an inch wide.

Solid axis distinct, the common body occupying a very small proportion of the whole width. Cellules elongate, distinctly curved, expanding; making an angle of from 30° to 35° with the axis; the aperture is twice as wide as

the base; the free portion is a little more than one third of the entire length. Margin of aperture slightly curved in the mature cell, and more distinctly in the young, making in the former an angle of 120° with the axis. The denticles are pointed, scarcely sub-mucronate, twenty-four in the space of an inch. Cell-partitions strongly marked, the line of separation extending nearly to the back of the stipe.

In this species the stipes resemble those of *G. bryonoides* in their width, form, and proportion of cellules and cell-denticles; but the number of stipes in entire specimens is a characteristic feature. In single stipes or in pairs of *G. octonarius*, there is, as shown in the figures, a longer space at the base without cellules, and in the double or quadruple stipes the difference of character is obvious. In the union of the two stipes in *G. bryonoides*, the funicle proceeds from the back of the stipes, or the non-celluliferous side; while in the union of two stipes in *G. octonarius*, the continuation below, uniting with the adjacent pair, is not from the back of the stipes alone, but the two appear to be united laterally and diverge at a different angle; as will be seen on comparing the figures of the two species. Fragments of *G. patulus* bear some resemblance to this species, but a comparison shows important differences.

EXPLANATIONS OF FIGURES OF GRAPTOLITHUS OCTONARIUS, Hall.

PLATE X.

1. A specimen of natural size, much broken and distorted from pressure.
2. An enlargement from the preceding figure.

Formation and Locality.—Shales of the Quebec group; Grôs Maule.

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20. GRAPTOLITHUS OCTOBRACHIATUS, Hall.

Plate VII, figures 1–7; and Plate VIII, figures 1–4.

(G. OCTOBRACHIATUS, Hall: *Geological Survey of Canada*, Report for 1857, page 122.)

Description.—Frond consisting of eight simple stipes, which are united in pairs at their bases: these have their origin from a short funicle, which proceeds from a radicle in the centre. Each extremity of the funicle is divided, and these divisions are again bifurcated, giving origin to the four stipes on each side, which are thus bilaterally arranged. The funicle and bases of the stipes are united in a broad thickened disc, composed of the same substance as the other parts of the fossil: disc octagonal, the

sides concave between the stipes, and the angles extended upon the margin of the stipes. Stipes robust, equal, linear, elongate, proceeding in right lines from the centre.

Within the disc or near it the stipes measure five hundredths of an inch in width; and beyond this the width, including the serrature, is thirteen hundredths of an inch. Test thick: the common body occupies sometimes about one third of the entire width. Cellules long, strongly curved, the breadth at the aperture three or four times as great as at the base; length a little more than three times the width at the aperture; making an angle with the axis of 20° near the base of the cell, and from 52° to 55° near the aperture. Margin of the aperture nearly straight, making an angle with the axis of 105°; and sometimes, when compressed, still greater. Denticles obtuse, about nineteen or twenty in the space of an inch.

This species is remarkable for its extremely elongate stipes and strong central disc. Some of the largest individuals, with the stipes expanded, have extended over an area of at least sixteen inches in diameter. The stipes are extremely robust, and in their original state appear to have been quadrangular; the measurement across the back of the stipe, when flattened, being seven ninths as great as the lateral measurement of the flattened stipe below the cell-denticles. The size of the stipes is not greater than in *G. Headi;* but these have a more rigid aspect, and are readily distinguishable when the cellules or cell-denticles can be seen.

All the specimens, with one exception, present the exterior or non-celluliferous side at the base; the disc and stipes adhering to the stone on the celluliferous face; so that it is only towards the extremities of the branches, where they are turned on one side, that the full width or form of the cellules can be seen. An impression of a short fragment of the celluliferous surface of one of the stipes shows strong deep indentations. The cellules vary but little in their distance or approximation, from seventeen to twenty in the space of an inch being the extremes of variation observed. The disc is not uniform in its proportions, nor regular in form, nor does it always appear to bear the same proportion to the strength of the stipes; it has sometimes a very symmetrical octagonal form: its substance is often considerably thickened and striated parallel to the margins, which are thinner, attenuating from the centre. The cellules are subject to variation from the direction in which the stipes have been compressed, and in this respect show a greater variety of appearances than any other species in the collection.

This species exhibits some differences in its mode of growth, and the number of stipes is not invariable. One specimen presents but seven stipes; the centre, funicle, and divisions on one side being of the normal character, while on the other, one division of the funicle does not bifurcate, but

continues as a single stipe, giving seven as the entire number of stipes, with a small seven-sided disc. In another individual we have five stipes only; the funicle and disc exist as in the others, but the subdivisions have taken place only on one side, while on the opposite the stipe continues simple. The presence or absence of the central disc, however, cannot be relied upon for specific or other distinction, since both in this species and *G. Logani* we have specimens of the same species, preserving their characters in all respects, except the disc. In the specimen fig. 2, plate viii, we have the central portion of an individual in which there is no evidence of the disc having existed. In its form and mode of division it corresponds in all respects with those specimens possessing the discs; and as it occurs in the same association, we cannot suppose it otherwise different.

In its long linear stipes, this species resembles *G. sagittarius* (Hall, Pal. New York, vol. i, plate 74, fig. 1; perhaps not the European species of that name); but the branches are stronger and the serrations coarser; it is moreover associated with a group of species, all of which are quite distinct from the New-York species with which *G. sagittarius* occurs.

Explanations of Figures of Graptolithus octobrachiatus, Hall.

Plate VII.

1. A large individual preserving two of the stipes to the length of eight inches, and another to nearly the same extent, while the rest are broken off at less distances from the disc. The flexibility of their substance is well shown in the recurved stipe at the left-hand side of the figures. Although this specimen preserves the most extended stipes of any in the collection, the disc is smaller than in several of the other specimens.
2. The exterior of a large disc of this species, with the stipes broken off a little beyond its margin. The two longer portions are so turned as to show the cellules.
3. A portion of a large disc, showing the exterior or non-celluliferous face of the frond, and preserving portions of four of the stipes.
4. A frond with the stipes broken off at different distances from the centre. The substance of the disc or cup is imperfect,—a condition which apparently existed while the body was in a living state.
5. An enlargement from one of the stipes at *c*, looking upon the apertures of the cellules, which are somewhat compressed.
6. An enlargement from the same at *b*, where the substance is laterally compressed.
7. An enlargement from the same, where the substance is obliquely compressed at *a*.

Figs. 5 & 7 are taken from casts made in the impressions left by removal of the substance of the graptolite.

Plate VIII.

1. A symmetrical frond preserving parts of all the stipes, two of them apparently almost entire; several of them had been abruptly bent before being imbedded in the stone.
2. A frond preserving eight stipes, but without a disc. The specimen does not afford any evidence that a disc has ever existed.

3. A frond with small disc and somewhat slender stipes. One side preserves the usual character of four stipes, while the other has but three.
4. A frond which is abnormally developed; one side preserving the four stipes with the disc, while on the other side the funicle is apparently extended in a single stipe only.

Formation and Locality.—Shales of the Quebec group; Point Lévis.

The *G. Logani* is the only species with numerous unbranched stipes which we know of at this time in the Quebec group. All the other species with more than eight stipes, have them branched beyond the commencement of the cellules. In the Hudson River formation, however, we have a single analogous species, the *G. multifasciatus*. In that one the stipes are forty or more in number, and are apparently simpler after they become celluliferous.

In the progress of development of the graptolites of this type, we have traced them through the two, four, and eight-stiped forms. Those with two stipes have never shown the cup or disc; while some of the latter two forms have discs, and others apparently never possessed this appendage. The subdivision into stipes appears to go on by a regular duplication of the parts; and the stipes in perfect forms are bilaterally arranged, beginning with those having two; which proceed, one on each side, from a rootlet. With the exception of *G. fruticosus*, the four-stiped forms originate from a minute radicle; while on each side of this centre, the body extends a short distance in the funicle, which is not celluliferous; and then subdivides equally, no cellules occurring below the division. In the next form, the funicle is divided at each extremity as before, and again divided or bifurcated below the origin of any cellules. Were this mode of subdivision to continue, the next step in the development would give us sixteen stipes; but we have no form of this kind in the collections.

In the next form, with simple stipes, we find the *G. Logani*, which presents a wide variation in the number of stipes; so varied indeed that the two extremes might, if examined separately and without the intermediate forms, be regarded as two distinct species. The variation in the number of stipes in this species extends from eighteen to twenty-five: some divisions of the funicle are equally, and others unequally developed in the number of stipes which proceed therefrom.

21. Graptolithus Logani, Hall.

Plate IX, figures 1–9; and Plate XI, figure 7.

(G. logani: *Geological Survey of Canada*, Report for 1857, page 115.)

Description.—Frond composed of numerous slender simple stipes, subequally disposed on the two sides of their origin, or of the minute point indicating the radicle. All these, in their perfect condition, have their bases embraced within a broad disc. Radicle sometimes well marked: funicle short, simple for about three sixteenths of an inch, when it is divided at each extremity, the divisions diverging at an angle of 150° or more. Each division is again subdivided with more or less regularity, and always near the base, until there are from eighteen to twenty-five simple stipes radiating from the central disc. There are rarely more than three bifurcations after the first division of the funicle, and these all take place within the limits of the disc. No cellules are visible on the stipes below the last bifurcation, though they do occur within the limits of the disc. On the inner or celluliferous side of the disc, the divisions of the funicle, and the bases of the stipes beyond, are grooved along the centre. The disc is from one to nearly two inches in diameter in different individuals, and with sides corresponding to the number of stipes, between which the margin is concave. The substance of the disc is corneous like that of the stipes, extremely thin, though composed of double walls; somewhat thickened near the centre, and forming only a thin translucent pellicle towards the margin. The surface is usually and perhaps always smooth in the centre; while towards the margin, and parallel with it, are fine striæ of growth.

The transverse diameter of the stipes, within the limits of the disc, is from two hundredths of an inch at the base to four hundredths of an inch at its outer margin. The vertical diameter, including the cell-denticles, is six hundredths of an inch. The stipe is thickened on the back, and about one fifth the width is occupied by the common body. The full width of the stipe is attained at about two inches from its origin. Some of the stipes have been traced for seven and a half inches from the centre of the disc, and their extremities are still imperfect. The cellules are short narrow and straight, making an angle with the axis of about 35°, and free for about two fifths of their length, which is less than three times the diameter of the aperture. The margin of the aperture makes an angle of from 90° to 95° with the axis: denticles acute, from twenty-two to twenty-six in the space of an inch; the prevailing number being twenty-four. Partition-walls thin, and obscurely marked on the surface of the stipe.

This species, when the form is entire, is readily recognized by its numerous simple elongated stipes. The separated central portions, whether

with or without the disc, may be known by the short funicle, and the numerous subdivisions near the centre. The stipes differ from those of any other species in their proportions, and the form of the cellules and denticles. In these separated parts there is some resemblance to *G. arcuatus;* but that species has the stipes more curved, with a different form of cell-denticle, and is moreover marked by the frequent occurrence of the minute radicle attached to the separated stipes, as well as by the presence of cellules nearer to the origin of the latter.

The great variation in the number of stipes shown to occur in *G. Logani*, as well as what occurs in a lesser degree in *G. octobrachiatus*, is sufficient evidence that strict specific characters cannot be founded on this feature alone, in species where the stipes are numerous. From what we are able to observe, it would appear that the disc of *G. octobrachiatus* extends itself with the age of the individual; though in *G. Logani* there is no perceptible difference in the width of the stipes near the base, whether the discs are larger or smaller. In those specimens of this species which are without the central disc, or where this part may have been removed, the stipes are always more slender towards the base than when they are embraced within the central disc.

The margins of the disc are slender, and sometimes found broken between some of the stipes, without injury to the rest of the body. The parts so broken assume the same outline as if entire, and may probably have been afterwards extended to correspond with the other portions. This feature is seen in plate IX, fig. 4, where a specimen preserving half of the disc shows that in three spaces between the stipes the disc had been partially broken away, and appears to have been in process of reproduction.

In specimens showing the inner side of the frond, we find a distinct groove marking the centre, the funicle, and the bases of the stipes: this is seen whether the disc is preserved or not, and appears to be an organic feature. This groove, corresponding to the central axis, likewise extends for some distance along the celluliferous portion of the stipe; and the indentation, being thus interrupted along the centre, is shown more strongly on each margin, appearing like a double indentation or serrature.

On the opposite side of the frond, when well preserved, the stipes near their bases, often appear to have a double axis, or an elevation on each side. This feature seems to be due to pressure, or to the filling of the tube on the two sides, while the centre has been contracted. It is clearly an accidental feature, probably dependent on the nature of the surrounding material, at least in part, since some specimens from their origin are full and round on the back of the stipes.

Explanations of Figures of Graptolithus Logani, Hall.

Plate IX.

1. A specimen of slate, preserving portions of three individuals, (two only given in the illustration.) The disc had probably been removed by maceration before they were imbedded, but the stipes are preserved to a length of more than seven inches. It does not appear that this exhibits the entire skeleton : the stipes were originally longer. The serrated margins are not always shown at equal distances from the centre ; but this is due to accidental position, some stipes showing the exterior surface for some distance, and then gradually turning and becoming flattened laterally.
2. A specimen showing the disc almost entire.
3. An individual showing the exterior surface ; the central portions entire, with the impression of the connecting disc, some portions of which remain attached to the stipes. The extent and outline of the disc are distinctly seen. The appearance of serratures is due to exfoliation, which shows the impression of the celluliferous side of the stipe upon the stone.
4. A specimen exhibiting the half of an individual, with the disc unequally extended between the rays. The margins are all apparently entire, and this inequality, to whatever accident due, existed in the living animal.
5. Exterior view of an individual showing some remaining portions of the disc ; the stipes are all broken off beyond the bifurcations.
6. Another individual showing the inner side, with the commencement of the cells, which appear in some places as if in double series ; the substance of the disc is removed.
7. Enlargement of the exterior surface of the central portion of the specimen fig. 5.
8. Enlargement of the inner surface of the specimen fig. 6, giving the appearance of a double series of cells separated by a depressed line in the substance of the stipe. Sometimes this separation appears to be actual, while elsewhere the apparent division is due to the depression along the centre.
9. Enlargement of a fragment of a stipe, showing the form and proportions of the cellules.

Plate XI.

7. The central part of an individual without disc, showing five stipes on one side and four on the other. This is supposed to be an abnormal form of *G. Logani.*

Formation and Locality.—Quebec group ; Point Lévis.

GRAPTOLITHUS FLEXILIS, Hall.

Plate X, figures 3–9.

(G. FLEXILIS, Hall: *Geological Survey of Canada*, Report for 1857, page 119.)

Description.—Frond multibrachiate, composed of numerous slender branching stipes, which are bilaterally disposed on the two sides of their origin. Radicle minute: funicle short, being little more than one tenth of an inch in length, dividing at the two extremities, the parts diverging at an angle of about 105°; each one of these again divides within the space of a tenth of an inch, making eight principal stipes, which are again several times bifurcated. Cellules commencing above the third bifurcation, perhaps above the second. Stipes slender flexuous, the branches diverging at a lesser angle at each successive bifurcation: stipes and branches filiform at base, and measuring in their full width, where the cellules are distinct, from four to seven hundredths of an inch, (a very small proportion of the width being occupied by the common body); curving from the base, and slightly arcuate in their entire length. The cellules are usually on the inner side of the curve. In the entire length from the first division of the funicle, four bifurcations may be counted, and these branches again divide. The subdivisions give about sixty-four branchlets in the entire frond, subject to some variation from the inconstancy of the subdivisions.

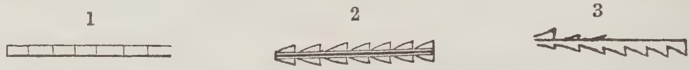
Cellules short straight narrow, inclined to the axis at an angle of about 30°; nearly one half the length of each cellule being free: length of cellules equal to about four times their diameter; the denticles acute, or acutely rounded, varying in the same stipe from about twenty-six to twenty-eight in the space of an inch; apertures making an angle with the axis of about 90°; cell-partitions obscurely marked, and traceable nearly to the back of the stipe. At the base of the branches the cellules are less developed, and sometimes appear as simple undulations of the margin.

This species is very distinctive in its features, both as to mode of growth and manner of bifurcation, as well as in the form and character of cell-denticles. In the first subdivision of the funicle and stipes, it might be mistaken on cursory examination for *G. Logani;* but the divergence of the first division is always less, and the second subdivisions always diverge at a different angle, while the branching of the stipes forms a very distinctive feature. The specimens examined show no evidence of ever having possessed a central disc. The substance of the stipe has an appearance of being more flexible than in any other species, though this character may be varied with the condition of preservation or the nature of the imbedding material. Under a lens, the axis and principal branches are rounded, with a thin corneous expansion or alation on each side, representing in a degree the central corneous cup or disc of other species.

In this species, the branches are sometimes compressed vertically (or in the direction from the celluliferous face to the back of the stipe), to such a degree as to give an apparent double serrature, or a celluliferous face on each side. In this condition, the cell-apertures are at right angles to the direction of the axis, or sloping a little backwards, with the extremities somewhat rounded. When the celluliferous side, thus compressed in the direction of the cellules, is uppermost on the surface of the shale, a line may sometimes be traced across the branch, joining the upper edges of the serratures, and being in fact the continuation of the cell-margins flattened against the stipe, while the extremities project on either side.

In this way we have a great variety of aspects: the smooth surface of the branch, with minute striations upon the outer side; the inner side, when not compressed, having cellules showing as indented lines across the surface (1); the double serration produced by a greater pressure in the same direction, or with the back of the stipe uppermost (2); again, as the branch is gradually turned around, these serratures disappear from one side, and become more prominent upon the other (3), finally showing their full breadth as the branch is compressed in its transverse or lateral direction.*

1 2 3



The specimens examined are in a finely laminated greenish-black shale.

EXPLANATIONS OF FIGURES OF GRAPTOLITHUS FLEXILIS, Hall.

PLATE X.

3. A fragment of slate preserving more than half of a frond, and showing the folding and crossing of some of the branches.
4. A fragment preserving parts of three individuals, the extremities of the branches all broken off.
5. The central portion of the frond of another individual.
6. Separated branches preserving the cellules in unusual perfection.
7. An enlargement of the centre of the frond, showing the short radicle and the usual mode of branching. The central part of the axis is rounded, with a narrow corneous alation at the sides.
8. A bifurcated fragment enlarged: the cellules have been flattened vertically, causing them to be visible in slight indentations on both sides of the axis.
9. A portion of a branchlet enlarged, showing one part compressed laterally, with the cellules fully expanded, while the other, on the right hand, is gradually twisted so as to show only the back of the branchlet.

Formation and Locality.—Quebec group; Point Lévis.

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* These illustrations of the effects of pressure upon the cellules were given in the Report of the Geological Survey of Canada for 1857.

Graptolithus rigidus, Hall.

Plate XI, figures 1–5.

(G. rigidus, Hall: *Geological Survey of Canada*, Report for 1857, page 121.)

Description.—Frond multibrachiate, composed of numerous slender branching stipes, equally disposed on the two sides of their origin. Radicle minute: funicle short, being a little more than one tenth of an inch in length, dividing at the two extremities, the divisions diverging at an angle of 115°; each stipe again bifurcating at least five times, following the principal axis, and occasionally six times in mature individuals; the principal branches again bifurcate twice or three times before reaching their termination.

In the first bifurcation of the stipe, (or second from the radicle,) the angle of divergence is about 78°, and in the second about 60°; while the succeeding divisions diverge at a less angle, and become somewhat curved. In one of the stipes beyond the first division (making one eighth of the entire frond) we are able to count fifteen bifurcations; giving eighteen branchlets to a secondary division of the stipe; or $18 \times 8, = 144$ in an entire frond, if uniformly branched as in the one examined.

Stipes and branches slender, cylindroid exteriorly, rigid, nearly uniform in width to the third bifurcation; all the measurements from the base giving about four hundredths of an inch diameter upon the outer side or back of the branches. A single specimen, which is apparently the upper side of the stipe, is nearly twice as wide as the above, and preserves a part of the solid axis: this is replaced by iron pyrites.

None of the specimens exhibit well-defined cellules below the last bifurcation, though some of the branches are obscurely undulating or denticulate on one side; but the specimens examined do not admit of a satisfactory determination of these characters.

The impossibility of tracing any evidence of cellules upon any part of the frond below the last bifurcations, suggests the possibility that this species was not celluliferous except at the extremities of the stipes or branches. In most of the specimens examined, these celluliferous parts have probably been broken off; since it is evident that the whole frond has been subjected to maceration, and even the stronger parts are often broken. The regularity of bifurcation is a remarkable feature, and furnishes a character by which even fragments of the species can be readily distinguished; smaller fragments may be known by their rigid wiry appearance.

Explanations of Figures of Graptolithus rigidus, Hall.

Plate XI.

1. A fragment preserving the centre and principal branches.
2. A larger specimen, showing the principal ramifications of the branches. This and the preceding specimen show only what appears to be the non-celluliferous portion of the frond.
3. The extreme parts of some branchlets laterally compressed, showing the celluliferous parts of the frond.
4. An enlargement of one of the branchlets of fig. 3.
5. A strong branch with part of the branchlets, showing the lower side or non-celluliferous portion of the frond.

Formation and Locality.—Quebec group; Point Lévis.

Graptolithus abnormis, Hall.

Plate XI, figure 6.

(G. abnormis, Hall: *Geological Survey of Canada*, Report for 1857, page 117.)

Description—Frond consisting of numerous slender bifurcating stipes, bilaterally arranged. Radicle minute; funicle long, bifurcating on each side; distance between the bifurcations one third of an inch; the divisions diverging at a little less than a right angle, while the inner subdivisions (or those adjacent to the radicle), after the second subdivision, diverge at right angles to the funicle. Stipes branching several times, one division showing four bifurcations beyond that of the funicle, giving ten branches for the quarter, or forty for the whole frond: stipes and subdivisions sub-cylindrical, being rounded on the lower side, grooved in the centre upon the upper side, and curving at the bifurcations: the width from one to two hundredths of an inch; free from cellules to the fourth division, counting that of the funicle as the first division. The stipes and branches maintain nearly the same dimensions throughout their entire length. Outer divisions apparently celluliferous. Cellules obscure, marked only by undulations upon the margin of the branches.

This species, in its general aspect, resembles *G. Logani* and *G. flexilis;* but differs in important particulars. The funicle is more slender, and nearly twice as long as in either of those species; the divisions of the funicle makes a lesser angle, and the divisions of the stipe near the base

are quite different. In the outer subdivisions it approaches in some degree to *G. flexilis*, the stipe being always more curved in its divergence at the bifurcation. The absence of cellules on all of the lower divisions of the stipe distinguishes this from any other species known to me at the present time, except *G. rigidus;* from which it differs in the manner of bifurcation and in the long slender funicle.

In the specimen before me there is a slight dissimilarity in the mode of branching on the two sides; but this relates only to details, and the specimen is imperfect, showing one of the main divisions, and only a small part of the other.

EXPLANATION OF FIGURE OF GRAPTOLITHUS ABNORMIS, Hall.

PLATE XI.

6. A fragment of slate preserving the centre and the branches on one side to beyond the first bifurcation. The other side is imperfect, and apparently less developed.

Formation and Locality.—Quebec group; Point Lévis.

GRAPTOLITHUS RICHARDSONI, Hall. (n. s.)

Plate XII, figures 1–8.

Description.—Frond consisting of strong sub-linear branching stipes, the number from their origin unknown; branchlets diverging at an angle of about 15°, and measuring in their transverse diameter about five hundredths of an inch; the vertical diameter from ten to fifteen hundredths of an inch. The test appears thick and somewhat striated; the cell-partitions often strongly marked; the common body occupying less than one fourth the width of the stipe. Cellules long and narrow, curving upwards, making an angle with the axis of from 25° to 35°; from four to six times as long as the width of the aperture, one fourth of the length or less being free: the angle of the aperture with the axis is about 140°; cell-denticles obtuse or obtusely pointed, eighteen or nineteen in the space of an inch.

The separated stipes of the species, when not branched, resemble those of *G. octobrachiatus*, but the cellules are more inclined, making a less angle with the axis, while the angle of the aperture is much greater. In the branching specimens, we have a character which distinguishes it from any other species.

The specimens examined have the cellules partially or entirely filled with iron pyrites, or other mineral matter, giving a nodose appearance upon the surface ; while the back of the specimens, when vertically compressed, is likewise nodose. We are not able to associate this form with the others according to the rule which we have adopted of commencing with the two-stiped forms, and thence going on successively to the more complex, or subdivided forms. It is probable however that this one, in its normal condition, had a form and mode of growth similar to *G. flexilis* and *G. rigidus*, but was of much stronger habit in all its parts.

EXPLANATIONS OF FIGURES OF GRAPTOLITHUS RICHARDSONI, Hall.

PLATE XII.

1. A fragment of slate, preserving a stipe, with six branches in its apparent continuation, and impressions of two others in the intermediate space ; two of these again bifurcating.
2. A fragment preserving several branchlets, which are compressed in different directions, showing the sides and apertures of the cellules.
3. An impression of a bifurcating fragment, the cellules of which were filled with mineral matter and vertically compressed.
4. A fragment of a branch laterally compressed.
5. The impression of a bifurcating branch where the cellules are somewhat obliquely compressed, and partially filled with mineral matter.
6. A fragment enlarged, giving a lateral view of the cellules.
7. An enlargement from an impression of a branchlet which was obliquely compressed, having the cellules filled with mineral matter.
8. Enlargement of a fragment where the cellules are filled with mineral matter and vertically compressed.

Formation and Locality.—In the shales of the Quebec group ; three miles above the river Ste. Anne.

GRAPTOLITHUS RAMULUS, Hall. (n. s.)

Plate XII, figures 9, 10.

Description.—The specimen described consists of a small branch showing two bifurcations : the substance is extremely thin and much compressed in soft finely laminated shale.

Stipe and branches slender, test thin, greatest width about four hundredths of an inch ; width of branches half as great. The common body occupies nearly one half the entire width of the stipe : branches diverging at an angle of 40° to 50°.

Cellules short and comparatively broad, inclined at an angle of about 25°, free for more than one half their length ; the length of cellules about two and a half times that of the aperture : margin of the aperture making an angle of about 140° with the axis : denticles or cell-extremities short and obtuse ; about twenty-eight in the space of an inch.

This species, in its mode of branching, form, and proportion of cell-denticles, differs from any other examined. It has a slight resemblance to *G. flexilis.*

Explanations of Figures of Dendrograptus ramulus, Hall.

Plate XII.

9. A small bifurcating branch.
10. An enlargement of fig. 9, showing the form and extent of the cellules.

Formation and Locality.—Quebec Group ; Point Lévis, below the village, in a loose mass of shale.

Genus DIPLOGRAPTUS, McCoy.

Diprion, Barrande ; *Petalolithus*, Suess.

Characters.—Frond simple (or compound ?). Stipes simple, flattened or quadrangular ; sides parallel or sub-parallel. Cellules arranged in a single series on the two sides of a double central axis : cellules oblique to the axis, the cell-apertures opening towards the apex ; cell-denticles prominent, often mucronate.

These forms are known only as simple stipes, which are supposed to have grown from a fixed root. From analogy with those which I have designated *Retiograptus*, I conceive they may have grown also in a compound form, proceeding from a central axis.

The genera *Retiolites*, *Retiograptus*, and *Phyllograptus* are, in some of these characters, similar to *Diplograptus ;* and some of the latter have been included under this designation. The mode of increase and arrangement of the cellules in those genera presents important differences ; and I would propose to restrict the term *Diplograptus* to such forms as are included in the above description, or those where the arrangement and growth of cellules are similar to those of *G. pristis*, *G. palmeus*, and *G. pristiniformis.*

The paucity of species and of individuals of this type is a remarkable feature in the collections from the Quebec group. It has scarcely been possible to find specimens for a proper illustration of the spec es.

DIPLOGRAPTUS PRISTINIFORMIS,* Hall.

Plate XIII, figures 15–17.

(GRAPTOLITHUS PRISTINIFORMIS, Hall: *Geological Survey of Canada*, Report for 1857, page 133; *Geology of Canada*, 1863, page 955. FUCOIDES DENTATUS: Brongniart, *Histoire des Végétaux Fossiles*, vol. 1, p. 70, 1828.

Description.—Stipe flattened simple sub-linear, celluliferous on the two sides, narrower at the base, obtuse, showing an extended slender radicle, gradually expanding above and obtaining its full width (about eight hundredths of an inch) within half an inch from the base. Cellules narrow, closely arranged; the free extremity sometimes acute, sometimes obtusely rounded; inclined to the axis at an angle of less than 20°; from six to eight times as long as wide, a little more than one third of their length free: angle of the aperture with the axis very variable, depending on the direction of the compression. About twenty-eight cellules in the space of an inch. Axis strong, often extending considerably beyond the celluliferous portion of the stipe, and sometimes marked by a groove indicating a line of separation.

This species bears some general resemblance to *G. pristis* (Pal. N. Y., vol. i, p. 265, pl. 72, fig. 1); but the stipe is narrower, and the cellules narrower and more closely arranged. In general form it resembles *G. angustifolius;* but in that species the margin is more deeply indented, the cell-denticles are always rounded, and the cellules inclined at a higher angle to the axis.

EXPLANATIONS OF FIGURES OF DIPLOGRAPTUS PRISTINIFORMIS, Hall.

PLATE XIII.

15. A fragment of a stipe, showing the usual form and proportions of the best-preserved specimens.
16. A smaller individual, with the mid-rib or axis extending beyond the body of the stipe.
17. An enlargement from fig. 16, showing more distinctly the form of the cellules.

Formation and Locality.—Quebec group; Point Lévis.

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* This species is probably identical with *Fucoides dentatus*, Brongniart, *ut cit.* See note under *G. bryonoides*, page 84.

Diplograptus inutilis, Hall. (n. s.)

Plate XIII, fig. 14.

Description.—Stipes, small and obscure, cellules angular, the free portions extending almost rectangularly to the axis, and produced into submucronate points. The cell-divisions cannot be traced beyond the serratures. The solid axis is slender, and extended beyond the celluliferous portion of the stipe.

These specimens occur as short stipes which preserve an extension of the solid axis, sometimes as great as the celluliferous portion. The distinguishing features are the angular extensions of the cellules, which are nearly equilateral, and sometimes slightly mucronate at their extremities.

This species occurs with *Climacograptus antennarius* and *Retiograptus ensiformis*, and has been observed in only a few specimens.

Formation and Locality.—Quebec group ; Point Lévis.

Genus CLIMACOGRAPTUS, Hall. (n. g.)

Simple stipes with sub-parallel margins, having a range of cellules on each side ; axis filiform ; cellules short and square ; apertures apparently excavated in the margin of the stipe, and transversely oval or subquadrate ; cell-denticles or appendages, if present, usually on the upper side of the aperture.

Several species of this type at present known are simple stipes with nearly parallel sides, marked by transversely-oval or quadrangular cell-apertures, which, when compressed against the body of the stipe, give the appearance of those forms described by Linnæus and subsequent authors as *Graptolithus scalaris*. In one species, where the stipe apparently preserves its natural proportions, the shorter diameter is about three fifths the longer diameter, and the axis is slender and filiform. In several of the species the axis is seen extending below the base of the cellules; while there is often a more or less extended oblique process from each side at the base, as shown in *C. antennarius* and *C. bicornis*. (Pl. xxiii, figs. 11, 13; and pl. A, figs. 13, 15, 16, and 17.)

These species are separated from such forms as *G. pristis* on account of the difference in form of cellules, or rather of cell-apertures, since the limit between the cellule and the body of the stipe is not easily observed in

flattened specimens. The species *Graptolithus* (*Climacograptus*) *bicornis* may be considered as the type of the genus; and I conceive that most of those described as *G. scalaris* are veritable species of this genus; among these I would cite pl. iii, figs. 5 and 6, and pl. ii, figs. 14, 15, and also figs. 7 and 8, Barrande, *Graptolites de Bohême*. In the latter figure the axis lies obliquely across the cell-apertures, a feature similar to that shown in plate A, fig. 14, of this memoir. *Graptolithus teretiusculus*, Hisinger, *G. rectangularis*, McCoy, and many of the figures on tab. i and tab. ii of Geinitz's *Graptolithen*, belong to this type.

In suggesting a generic name, I have recognized the original specific designation of Linnæus, *G. scalaris*.

The form of cellules in the peculiar group of which *G. ramosus* may be considered the type, is very similar to *G. bicornis*, and should be separated from *Graptolithus* proper for the same reason, forming a sub-generic group, for which I suggest the name of *Dicranograptus*.

Climacograptus antennarius, Hall.

Plate XIII, figures 11–13.

(Graptolithus antennarius, Hall: *Geology of Canada*, 1863, page 955.)

Description.—Stipes small, simple, quadrangular, flattened, slightly narrowed towards the base. In their natural condition they have been slender sub-quadrangular tubes, celluliferous on two sides, and having a width when flattened, including the denticles, of thirteen hundredths of an inch. Axis strong, extending beyond the upper extremity of the stipe, and sometimes marked by a longitudinal groove: base obtusely pointed, and having the axis slightly extended in the middle with two setiform processes, one from each side, diverging at an angle of about 60° with the axis, and slightly curved, the two including an angle of from 120° to 125°. Cellules short, nearly twice as wide as long; cell-denticles nearly rectangular to the axis, and frequently inclined; from about twenty-four to twenty-eight in the space of an inch. Surface smooth, and the test extremely thin.

Under this species I have included individuals having the same habit and form, but varying in the distance of the cellules, and presenting much variety of aspect from the different directions in which the stipe has been compressed. In some examples, the margins of the stipes present rectangularly-projecting processes or spinules, which vary from being barely

visible to having sometimes a length equal to one third the width of the stipe. Sometimes the margins of the stipes are entirely smooth and straight, and the flattened surface shows indentations produced by the cellules. Often the surfaces are so nearly smooth that these indentations may be readily overlooked. In those flattened stipes where the margins are straight, or where only minute points are visible on the margin, the width varies from nine to eleven hundredths of an inch.

In all well-preserved specimens, whatever the aspect of the cellules, the basal processes or radicles are nearly constant in presence and direction ; and the solid axis always projects beyond the upper end of the stipe, and sometimes to the extent of an inch beyond the celluliferous portion. In the extension of the cell-denticles upon the margins of the stipe, in the condition represented in fig. 12, the specimens bear some resemblance to *Retiograptus*.

Explanations of Figures of Climacograptus antennarius, Hall.

Plate XIII.

11. A young individual, compressed in such a manner that the cell-apertures are not shown upon the margin.
12. A flattened stipe, presenting only the mucronate terminations of the cell-apertures beyond the margin.
13. An older individual, showing the margins of the stipe extending beyond the cell-apertures, while the cellules are visible in the substance of the stipes as darker areas.

Formation and Locality.—Quebec group ; Point Lévis.

Genus RETIOLITES, Barrande.

Generic characters.—Stipes thin, flat, elongate, triangular, composed of two series of cellules symmetrically arranged in regard to the axis of the figure. The cellules arise from a single internal canal which occupies the central portion of the stipe. The cell-orifices are disposed upon the sides of the triangle, making an acute angle with the axis, and leave no space between themselves.

The above is essentially the description of this genus given by Mr. Barrande.

The species from the Clinton group, which I have referred to this genus is extremely flattened, and it is not possible to determine that it has a triangular form. It possesses a very distinct axis and cell-divisions, which however may sometimes be concealed by the reticulate covering. In the

Canadian species I have not been able to discover a reticulate structure similar to the European species, nor like that from the Clinton group of New York; but there is sometimes an apparent punctate texture, and the test is thickened. Although the axis and cell-divisions are usually distinctly visible, they have not the characters of *Diplograptus*.

The *R. Geinitzianus* of Barrande is found in Bohemia and Saxony at the base of the Upper Silurian, and probably not far from the same horizon as the American species *R. venosus*.

The *R. ensiformis* of the Quebec group holds a much lower geological position, which, together with the difference of structure, leads me to suppose that it may ultimately be separated as a distinct genus.

Retiolites ensiformis, Hall.

Plate XIV, figures 1–5.

(Graptolithus ensiformis, Hall: *Geological Survey of Canada*, Report for 1850, p. 133.)

Description.—Stipe simple, sub-ensiform or elongate-lanceolate, usually broader in the middle and narrower towards the extremities: axis central, with strongly-marked obliquely ascending striæ reaching to the margins. Cellules obscure, apparently corresponding to the striæ; margin usually well defined. Width of stipe, in the largest individuals, sixteen hundredths of an inch; length nearly two and a half inches. Other specimens have a width of one twentieth of an inch, with a length of half an inch. Cellules about twenty-eight in the space of an inch, inclined to the axis at an angle of about 50°, and without any appreciable portion being free. The solid axis is slightly undulating, and the cell-partitions alternate on the two sides of it, thus separating the cellules from each other. In some specimens the base is rounded and obtuse; others show a continuation of the axis, or a central straight radicle. Substance of the test punctate.

All the specimens are extremely flattened, and it is very difficult to distinguish any difference in the opposite sides of individuals. In the best-defined specimen there is a distinct axis with alternate diverging filaments or cell-divisions, which reach to the outer margin, the substance being nearly all removed except this skeleton. In a single specimen, the axis is not strictly defined, and is broader, while the diverging partitions are less strongly marked. This one affords the only evidence that we have of the difference in the two sides of the species, a difference shown in the *R. Geinitzianus* of Barrande.

In the punctate test and undulating axis, we have the characteristics of *Retiolites*, which, as illustrated by Geinitz, shows on one side the cell-partitions reaching to the well-defined axis. The same feature of *Retiolites* is shown in a still stronger degree in the figures of Edward Suess.*

EXPLANATIONS OF FIGURES OF RETIOLITES ENSIFORMIS, Hall.

PLATE XIV.

1, 2, 3. Individuals showing gradations in growth, and slight differences in their proportions.
4. A nearly entire stipe of the largest size observed.
5. An enlargement from the specimen fig. 4.

Formation and Locality.—Quebec group ; near Point Lévis.

GENUS RETIOGRAPTUS,† Hall.

Generic characters.—Frond simple ? or compound, consisting of numerous simple stipes in bilateral arrangement, proceeding from an axis or radicle, (or of single stipes growing from their own radicles ?) Stipes elongate-oval, or lanceolate, with longitudinal axis and reticulate structure; margins ornamented with mucronate points. The axis often extends beyond the substance of the stipe in a mucronate tip, and in one species there are long setæ extending from what appears to be the base of the stipes.

I had originally referred the *Retiograptus tentaculatus* to the genus *Retiolites* of Barrande (describing it under the genus *Graptolithus*). A farther examination of its structure, together with that of a species from the shales of Norman's Kill near Albany, induced me to separate them from *Retiolites*, and propose the name of *Retiograptus*. Subsequently an examination of some specimens from the Utica formation from Lake St. John in Canada, revealed a minute compound form which is illustrated in fig. 9 of pl. xiv. Although presenting some slight differences from the other two known species, I conceive it not to be generically separable from them. The specimen is extremely interesting for its illustration of a mode of growth

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* Ueber Bömischen Graptolithen, von Edward Suess. Naturwissenschaftliche Abhandlungen, IV Band, IV Abth. Tab. VII, 1851.

† A species of this genus has been describe din the third volume of the Palæontology of New-York, Supplement, p. 518; and in the Thirteenth Report on the State Cabinet of Natural History ; but no generic description was given.

not before known in forms of this kind, and suggests the possibility, if not the probability, that some others of the bi-celluliferous or diprionidian forms may have grown with this compound arrangement of the parts.

The stipes of the specimen figure 9, if separated, present an aspect very analogous to those of *Diplograptus* and *Retiolites*, and would not be supposed to have had any different mode of growth. The setiform processes at the base of some of the species may be regarded as an objection to the compound mode of growth; but this feature would offer a still greater objection to regarding those stipes as simple, and as having grown from an independent radix. The three species of the genus now known to me, present some important points of difference one from the other, and there still remains some obscurity regarding the arrangement of the cellules.

These forms are nearly related to the *Retiolites* of Barrande; but the texture of the specimens examined, and the arrangement of the parts, differ so much from authentic specimens of *R. Geinitzianus*, that I have separated them under the above designation.

Retiograptus tentaculatus, Hall.

Plate XIV, figures 6–8.

(Graptolithus tentaculatus: (Genus *Retiolites*, Barrande) *Geological Survey of Canada*, Report for 1857, p. 134.)

Description.—Original form of the entire frond unknown. Stipes simple, narrow, very elongate-elliptical when entire, narrower at the base, and gradually expanding above to the middle of their length; where they attain the greatest width, and become gradually narrower above, with the apex obtuse or rounded.

Central axis strong and well defined, extending beyond the stipe a distance equal to half its length: base furnished with two elongate diverging setæ, which extending from the outer edges, gradually curve downwards, and finally assume a direction nearly parallel to the axis. Within these long outer processes, and proceeding from the centre of the base of the stipe, there is an extension of the filiform axis, which sometimes appears in its duplicate character.

Exterior margins reticulate, furnished with a row of hexagonal meshes, separated by slender processes extending from the substance of the stipe, which unite in a continuous filiform border; from this proceed, at about every second reticulation, short setiform spines, which in the middle of the length of the stipe are rectangular to the axis, while nearer to the base

and to the apex they are inclined towards the axis in opposite directions. These spines are sometimes on the outer margin of each mesh, and sometimes visible only on every third one. With these rows of meshes, when preserved, the stipe has the appearance of a flattened corneous film with a central axis, which is divided into cellules as in other forms of *Graptolitidæ;* and when the outer meshes are broken off, these cell-divisions project as mucronate points beyond the margin of the stipe. These marginal meshes correspond to the divisions of the stipe marked by the cell-partitions, and might be regarded as showing the limits of the cell-apertures, which have opened obliquely to the transverse direction of the stipe. These meshes or cellules are arranged in the proportion of about twenty-eight in the space of an inch, the stipes being usually nearly three fourths of an inch (the longest one eighty-three hundredths) in length.

We have no evidence that the test is punctate, and it has all the appearance of the ordinary graptolites. The greatest width observed in any stipe, exclusive of the marginal meshes, is seventeen hundredths of an inch. In one specimen the extreme length of the stipe, exclusive of the radicles and extended axis, is seventy hundredths of an inch; and the width, exclusive of the meshes, is fifteen hundredths, and including the meshes, twenty hundredths of an inch.

The specimens examined are all extremely compressed, so that it is impossible to determine any points of structure beyond those presented upon the surface. I do not suppose that the original form has been that of a flattened stipe, but rather of a quadrangular or fusiform sac, perhaps even convex on one side and flat or concave on the other. The cell-divisions are traceable almost to the central axis; and it is the continuations of these that form the reticulation of the margin, and are again produced in setiform spines. It is impossible to reconcile a structure like this with any thing previously described among the *Graptolitidæ;* and though our views of their structure may be somewhat modified by an examination of better preserved specimens, they cannot be united with the ordinary forms; so that while *Retiolites* is separated from *Graptolithus* proper, we may regard this form as equally entitled to generic designation.

EXPLANATIONS OF FIGURES OF RETIOGRAPTUS TENTACULATUS, Hall.

PLATE XIV.

6. An individual of the natural size, with the marginal reticulations nearly entire.
7. The preceding specimen enlarged.
8. An enlargement of another individual, where the marginal reticulations are but partially preserved.
9. An illustration of a compound form of *Retiograptus* (*R. eucharis*), from the Utica formation of Lake St. John. (For a description of this species, see Appendix.)

Formation and Locality.—Quebec group; Point Lévis.

GENUS PHYLLOGRAPTUS, Hall.

Gr. Φυλλον, *folium*, and γραφω, *scribo*.

(PHYLLOGRAPTUS: *Geological Survey of Canada*, Report for 1857, page 135.)

Generic characters.—Frond consisting of simple or compound foliiform stipes, which are celluliferous upon the two opposite sides, the margins having a mucronate extension from each cellule: or consisting of similar forms united rectangularly to each other by their longitudinal axes, and furnished on their outer margins with similar cellules; the whole supported on a slender radicle, or combined in groups.

These forms are analogous in structure to *Diplograptus;* but instead of two simple stipes united by their solid axes, we have in the examples illustrated, four stipes united in a similar manner, giving four separate and independant sets of cellules. The cellules have likewise a proportionally greater development, giving a broader form to the stipes than in typical species of *Diplograptus*. These bodies, which usually appear upon the stone as simple leaf-like expansions, may have been attached in groups to some other support; but the forms of most of them, and the character of the projecting radicle at the base, give the same indication of the entireness of the frond that we have in ordinary forms of *Diplograptus*.

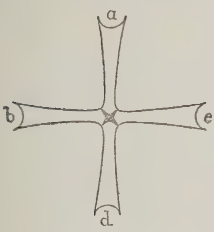
Of all the *Graptolitidæ*, these forms furnish perhaps the best illustration of the lesser development of the cells at the base of the axis, and of their gradual expansion above, as far as the middle or upper part of the stipe. Many of them diminish from the centre upwards, and rarely the cells are more developed above the centre, reversing the usual mode, and leaving the narrower part at the base.

When bodies of this form were thrown down upon a muddy sea-bottom, they would become imbedded mainly in two positions. The most common position appears to be that in which the parts retain a vertical and a horizontal direction, as in fig. 1; the lower division or folium *d* would thus become first imbedded; while the folia *b*, *c* would lie in the plane of deposition, and *a* would be the last imbedded. The slaty laminæ separate along the line *b*, *c*, either above or below the folia *b*, *c;* leaving on one side the folia and on the other their impression. If the separation takes place above, then the bases of the cellules of *a* remain; these are directed obliquely downwards towards the base of the stipe. If the separation takes place below the folia *b*, *c*, the cellules of folium *d* are seen directed upwards, or towards the apex of the stipe. These modes of separation would present appearances like figs. 4 and 8, pl. xv; fig. 4, pl. xvi; and figs. 5 and 15, pl. xvi.

The other direction of imbedding would be when the specimens were so deposited that the laminæ rested obliquely to the plane of stratifica-

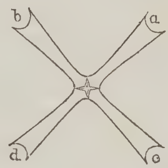
tion, as in fig. 2. In this way, from the accumulation of the sediment, they would become compressed, as in fig. 3, until the parts *b*, *d*, and *a*, *c* would approach each other, or come in contact. Lying thus, with the slaty laminæ separating above or below them, they would present the aspects of figs. 6 and 9, pl. xv; and of fig. 8, plate xvi.

1



2

3



When the parts *b*, *a* are removed, the parts *d*, *c* remain, showing the base of the cellules, as in figs. 4 and 5, pl. xv, and figs. 3 and 7, pl. xvi; while in the examples where the margins only are removed, we have appearances like fig. 9, pl. xvi.

PHYLLOGRAPTUS TYPUS, Hall.

Plate XV, figures 1–12.

(PHYLLOGRAPTUS TYPUS: *Geological Survey of Canada*, Report for 1857, page 137.)

Description.—Stipes robust, composed of four semi-elliptical parts joined by their straight sides. As preserved upon the shale, these bodies are elongate-ovate or lanceolate, broad oval or obovate: cellules about twenty-four, rarely twenty-two, and sometimes twenty-six in the space of an inch, usually obscure at the margin; axis or mid-rib broad, often crenulate or serrate; radicle usually short; in some specimens about half an inch in length being preserved.

The stipe originates from a slender pointed radicle. The cellules near the base are short, coming out almost rectangularly to the axis, or slightly ascending and gradually increasing in width, curving backwards or downwards, and having the aperture sometimes nearly at right angles to the axis: the curvature lessens towards the middle of the stipe, and the line of aperture is parallel to the axis; while above this they are inclined towards the axis, and near the summit they are again nearly at right angles to the axis, but opening in a direction opposite to those near the base. Cell-

apertures mucronate by the continuation of the cell-partitions, the mucronate appendages sometimes appearing to be double, as if each angle of the aperture had been thus ornamented.* Central axis linear, from half a line to nearly a line in width. In some examples there is an apparently greater width, which is probably due to a slipping of the test. This central axis is often crenulate from the bases or impressions of cellules of the other division, which is rectangular to that part of the frond preserved.

This species assumes a variety of forms, and, from an examination of specimens of the extremes, they might be regarded as distinct species. After examining several hundred specimens however, I am not able to find constant characters to establish specific differences. The individuals figured represent the principal varieties. I have not thus far observed forms intermediate between the short broad and the elongate-oval ones, but they may be found in larger collections. The number of cellules in entire fronds varies in different individuals from twenty-five to fifty on each side, according to the size and form of the specimen.

The specimens are all compressed, and the rectangular arrangement of the parts of the frond, as seen in *P. ilicifolius*, cannot be seen in these; the evidence of this character being the serratures along the central axis, which are transverse to those of the two sides. The proportions of length and breadth vary extremely; one of the broad forms has a width of five tenths of an inch, with a length of eight tenths of an inch, while a long form is two and an eighth inches in length and six tenths of an inch wide in the widest part.

In a single fragment of the shale containing this species, the number of individual stipes within a small space is so great as to suggest the probability that these have originated from a common axis, as in *Retiograptus*, and have been separated but a little distance from their centre of attachment. With one exception, all these are of small size, and present no greater variation than is observed in the stipes of a single frond of *Retiograptus*, fig. 9, plate xiv.

EXPLANATIONS OF FIGURES OF PHYLLOGRAPTUS TYPUS, Hall.

PLATE XV.

1. An extremely short and broad form of this species, with the axis broad, and showing some remains of the cellules at the base of the separated division.
2. An elongate-ovate form of stipe, with a broad axis, which does not show remains of cellules. Some of the cellules in the upper part of the stipe are filled with iron pyrites.

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* This feature may possibly be sometimes due to the overlapping of two adjacent folia, so as to bring the cell-partitions and cell-denticles near to and parallel with each other, showing a denticle from each one.

3. A form similar to the preceding, showing remains of cellules on the upper part of the axis.
4. An elliptical form of stipe, where two of the divisions have been separated, leaving the bases of two sets of cellules.
5. A broadly-elliptical form, from which two of the divisions and the axis have been removed; showing the bases of the cellules of the folia remaining in the slate.
6. A stipe compressed in the same direction as fig. 3 of the generic illustrations, page 119; with a part of one of the folia removed, but not reaching to the axis. The lines of the cell-partitions appear as if continued across the axis.
7. An elongate-lanceolate form of stipe, which does not show cellules in the line of the axis.
8. An elongate-elliptical and very symmetrical specimen, showing the marks of cellules along the axis, which is unusually narrow.
9. A part of a stipe folded in the manner of fig. 6, the upper portion of one side preserving only the impression of the substance. In the lower part, the cell-markings on the axis should be shown more distinctly.
10. A group of small stipes upon the surface of a piece of shale. These are given in their natural size and in their actual relations to each other.
11. An enlargement of a part of an impression of a stipe which has been flattened in the direction of figs. 6 and 9. A portion of the substance remains, as shown on the left hand; the cellules filled with iron pyrites.
12. An enlarged portion from a stipe, showing the double cell-denticles and corresponding cell-partitions. The narrow spaces on the surface of the figure are more elevated than the wider ones, with a greater thickness of the substance; which I suppose may have been caused by the cell-partitions, which are obliquely compressed, thus showing the cell-denticles. These elevated spaces become gradually narrower towards the axis, in accordance with the form of the cells, as shown in the theoretical figure 10, plate xvi.

Formation and Locality.—Quebec group; Point Lévis.

Phyllograptus ilicifolius, Hall.

Plate XVI, figures 1–10.

(Ph. ilicifolius: *Geological Survey of Canada*, Report for 1857, page 139.)

Description.—Frond broadly oval or ovate: axis broad; radicle short; cellules from twenty-eight to thirty-two in the space of an inch, varying slightly with the proportionate length of the frond.

The radicle is rarely visible in the specimens examined. The cellules from the base are at first slightly ascending, and gradually curve outwards and downwards, so that the line of aperture is nearly rectangular to the

axis. This curvature becomes less in the higher cellules; those of the middle open nearly parallel to the axis, and finally at the summit open in a direction opposite to those of the base. Cell-apertures mucronate, by the extension of the cell-partitions beyond the opening, in nearly their full width; but seen upon the edge, they appear as setiform processes. The test is striated parallel to the cell-apertures, which have a concave outline.

As the specimens lie upon the surface of the shale, the central portion, for about half a line in width, is usually rough, and the broken cellules are clearly distinguishable; while on each side are the semi-oval divisions of the frond, with the cellules spreading from the céntral axis.

The entire frond in reality consists of four semi-oval or sémi-ovate folia, which are joined rectangularly by their longitudinal axes, and in a transverse section present a regular cruciform figure. The expansions of the two sides, when laterally compressed, show distinct cellules with projecting mucronate extensions: those which are vertically compressed have the outer portions broken off in the separated laminæ of slate, and present the bases of the cells; which have been sometimes filled with mineral matter, and distended before being imbedded. In a few instances the cells of the lateral portions are filled in the same manner, appearing as curving conical tubes with the broader extremities outwards.

When the bases of the cellules of the upper or nearest of the folia remain, they are seen to be directed obliquely downwards to the axis; but sometimes in the process of separation these bases are removed wholly or in part, and the bases of the opposite folium are seen below the plane of the two lateral folia, or their impressions, which are spread out on the surface of the slaty lamina: these cellules are then clearly observed to be directed upwards, as we see them from below.

It not unfrequently happens that this broad celluliferous axis is reduced to an undulating line, which results from compression in a direction oblique to the rectangularly-arranged folia, as in fig. 2, page 119, so that the two adjacent parts are spread out, and consequently no central line of cellules would be seen. When these have been divided longitudinally a little on one side of the centre, two sets of cellules are often seen penetrating the stone in oblique directions to the laminæ of shale.

The condition of preservation in several specimens examined is such as to render unavoidable the conclusion which I have given above, as to their mode of growth, however anomalous it may seem.

This species differs from *P. typus* in its thicker substance, proportionally shorter and broader form, and more closely-arranged cellules.

Explanations of Figures of Phyllograptus ilicifolius, Hall.

Plate XVI.

1. An individual of the natural size, where the folia *b*, *a** are broken entirely away beyond the axis, leaving the bases of the cellules of two adjacent folia visible except at the upper part of the figure, where two or three of the bases of the other cellules remain.
2. A similar specimen, showing the bases of a set of cellules on each side of the centre, with two or three of those belonging to the broken folium at the base of the figure.
3. An enlargement of fig. 2, showing more distinctly the cellules on each side of the central line, and the small remaining portion at the base.
4. A specimen of the natural size, where one folium is broken away not quite so far as the axis, leaving the bases of its cellules visible.
5. An enlarged figure from a specimen which has been imbedded transversely. Three of the divisions have been broken away, leaving impressions of the lateral ones only, and of the cell-bases, and cell-partitions of the fourth division, which are directed obliquely upwards from the axis and point of view. The lower part of the specimen preserves a portion of the lateral folia, with the bases of the cells of the outer division *a**, which are directed towards the axis.
6. An enlargement of a specimen which is imbedded obliquely, or in a direction as if the theoretical figure 10 were vertically compressed, leaving no visible axis. In the lower half of the specimen, the fossil has been separated in the opposite slaty laminæ, leaving only the impression of the opposite side, which also shows no axis. In the upper half of the specimen, the cellules are well preserved, and on the left-hand side the apertures are conspicuous. Enlarged to three diameters.

   It will be observed that the impression is not quite in the same direction as the outline in theupper portion of the figure, owing to the obliquely-compressed folia.
7. A specimen compressed in the same manner as fig. 6; the upper folia have however been separated, except the bases of a few of the cellules in the upper part of the figure, leaving the other two folia imbedded in the shale, and showing the bases of their cellules ascending from the axis. Enlarged to three diameters, as in fig. 6.
8. An enlarged figure of a specimen compressed in the direction first described, without any separation of the parts; from which cause there is no proper axis visible. In this condition, the specimens resemble *Graptolithus folium* of Hisinger, or *G. ovatus* of Barrande.
9. An enlargement of a specimen compressed as in fig. 8, but with the cellules filled, and the margins of the upper two folia broken, showing the cell-openings. (8 and 9 are enlarged to twice their natural size.)
10. A restoration of the form of *P. ilicifolius*, showing the four divisions; which are represented as cut through transversely, exhibiting the cell-cavities.

Formation and Locality.—Quebec group; Point Lévis.

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* These letters refer to the illustrative figures on page 119.

Phyllograptus Anna, Hall. (n. s.)

Plate XVI, figures 11–16.

Description.—Consisting of flattened elliptical stipes, which are sometimes broader above. Radicle minute: margins celluliferous, the cell-apertures furnished with long mucronate extensions. Cellules rising from the axis, expanding in width, and curving outwards and downwards; the curvature diminishing in the middle, while the upper ones are but slightly curved: margins of the apertures regularly concave between the extensions of the cell-partitions, distinctly striated upon the sides parallel to the margins. Axis celluliferous, its width five hundredths of an inch in a specimen of forty-three hundredths of an inch in length, the entire width of the specimen being twenty hundredths of an inch: cellules in the proportion of from thirty-six to thirty-eight in the space of an inch.

This species is shorter in proportion to its length than either of the others; the individuals rarely or never reach the length of half an inch, and vary from one eighth to seven sixteenths of an inch. The test appears to be thicker, and the cellules more distinctly marked than in *P. angustifolius;* while its smaller size and more closely-arranged cellules distinguish it from the other species.

Explanations of Figures of Phyllograptus Anna, Hall.

Plate XVI.

11. A specimen with the folia obliquely compressed.

12, 13, 14. Individuals showing some varieties of form. The specimens have all been so imbedded that one of the folia has been torn away in the separated laminæ of shale, leaving an axis marked by the bases of its cellules.

15. An enlargement of a specimen which has one of the laminæ vertically imbedded, and shows the bases of the cells as they recede from the axis. The markings at the sides are from the impressions of the folia, except a small fragment of one remaining on the left-hand side of the figure.

16. An enlargement from a specimen where the two lateral folia remain, showing the bases of the cells of the folium which has been broken off, in the separated laminæ of slate. The surface is distinctly striated.

Formation and Locality.—Quebec group; three miles above the river Ste. Anne.

Phyllograptus angustifolius, Hall.

Plate XVI, figures 17–21.

(Ph. angustifolius, Hall : *Geological Survey of Canada*, Report for 1857, page 139.)

Description.—The stipes, as seen on the slaty laminæ, are elongato-elliptical or elongato-lanceolate, being usually a little broader near the base. Radicle scarcely visible: margins celluliferous ; cellules about twenty-four in the space of an inch (rarely twenty-six, while one short broad form shows twenty-eight) ; cell-apertures with an elongate triangular denticle, which is mucronate at the extremity : the denticle is once and a half as long as the width of the cell. Central axis from three to four hundredths of an inch in width, obscurely indented by the cellules of the other divisions of the frond.

This species differs from either of the preceding in its narrow and elongate form. The specimens are numerous, but being for the most part on slaty laminæ which are extremely compressed, they preserve scarcely any substance ; a mere outline, with a more brilliant surface than the rest of the rock, being almost the only remaining characterby which they are recognized. In a few individuals the test is better preserved, showing a moderate thickness. The cell-margins on the upper side are less extended on the cell-partitions than in the preceding species ; while on the lower side they are equally or more extended, giving a form of aperture different from that of the other species, and a different denticle.

Explanations of Figures of Phyllograptus augustifolius, Hall.

Plate XVI.

17. A small and comparatively wide specimen, with a distinct linear axis, but without evidence of cellules.

18. A more elongate specimen, with distinct axis, with a darker line in the centre.

19, 20, 21. Varieties of form and proportion. The specimen fig. 21 is the largest observed.

This species is placed under *Phyllograptus* from its similarity in form to others of the genus, although evidence of the quadruple division has not been established. The want of parallelism of the margins, and the sub-elliptical form would, I conceive, be sufficient to remove it from the genus *Diplograptus.*

Formation and Locality.—Quebec group ; Point Lévis.

Genus DENDROGRAPTUS, Hall.

Gr. δενδρον, *arbor*, and γραφω, *scribo*.

Generic characters.—Fronds simple or aggregate, consisting of a strong footstalk, which is sometimes furnished below with a distinct root or root-like bulb, and above is variously ramified, and subdivided into numerous branches and branchlets, which are but slightly divergent; the whole producing a broad spreading shrub-like frond; (fronds sometimes flabellate?). Branches celluliferous on one side: cellules appearing sometimes as simple indentations on the surface, and sometimes distinctly angular, with the denticles conspicuous. In some specimens the cellules are indicated by prominent pustule-like elevations, arranged along the centre, or in sub-alternate order on one face of the branch. Substance of the stipe and branches corneous, solid or tubular: surface striated.

These bodies present specific distinctions in the strength of the stipe or stem, in the mode of bifurcation and number of branches, in the character of the surface, and in the general form of the frond. The celluliferous side usually adheres to the stone, and we perceive only some simple undulations or unequal thickening of the back of the branches. Often the branches have an alation on one side, like a thin pellicle flattened and extended along the more solid axis. The radix or radicle consists of an expansion of the footstalk, and in one species appears like a flattened bulb or disc, of irregular form. The footstalks, when well preserved, are marked by interrupted longitudinal striæ, and the non-celluliferous faces of the branches are variously striated, the striæ in most instances being unequal or interrupted in their course.

In the study of the fossils of this general character, I have indicated the species from the Potsdam sandstone of the Mississippi valley as the typical form of the genus. In this one, the cell-denticles are quite conspicuous and distinctly angular; while in some of the species from the Quebec group, the form of the cell-denticles is obscure, and in others it is shown only as a round or elliptical pit or pustule, depending on the condition of preservation. These differences in the form of the cellule lead me to suppose that a farther subdivision of this group may become necessary; but in the condition of the specimens in the collection before me, I do not feel justified in attempting to do this at the present time.

There is likewise a gradation in the mode of growth among the species, by which there is an apparent transition from the form of *Dendrograptus* proper, to those similar to *Dictyonema*. I have thought it necessary to separate two forms of the latter type under another designation.

The following figures, already published in the Geological Report of Wisconsin, illustrate the character of the species of this genus from the Potsdam sandstone.

a b c

Dendrograptus Hallianus, Prout.

a. A portion of the frond, of the natural size.
b. An enlargement of one of the branchlets, showing the cellules.
c. The main stipe and some of the principal branchlets, natural size. There is an expansion or protuberance at the base or radicle, one side of which is broken off.

Dendrograptus flexuosus, Hall. (n. s.)

Plate XVII, figures 1, 2.

Description.—Frond broadly expanding. Stipe short, flexuous, branching near the base: branches somewhat regularly bifurcating, the divisions sub-equal in strength and equally diverging. Stipe and branches flattened, (round in their original form,) very gradually diminishing towards their extremities, flexuous, the margins of the lower ones scarcely undulating; the upper ones more distinctly undulating, and sometimes showing the cell-denticles when viewed upon the non-celluliferous side. Cellules long, narrow, extremities free: cell-denticles angular, about thirty-three in the space of an inch.

This species is less robust than *D. fruticosus*, the stipe more flexuous, the branches proportionally broader, their divergence more equal and at a greater angle, giving a wider expansion to the frond. The branches

are not so distinctly undulated by the projection of the cells, and whenever these are visible, the form of the aperture or cell-denticle is a distinguishing feature.

In a specimen of coarse greenish or olive shale, which contains this species, we find also a few fragments of graptolites, among which we recognize *G. bryonoides;* and in another specimen of coarse brown shale, we find it associated with *Phyllograptus typus* and *Dendrograptus fruticosus.*

EXPLANATIONS OF FIGURES OF DENDROGRAPTUS FLEXUOSUS, Hall.

PLATE XVII.

1. A small frond of the natural size.
2. A part of a larger frond.

The characters of the cellules and denticles referred to in the description, are derived from some branchlets of the specimen figure 2, which show these features in a very satisfactory manner. The illustration was unintentionally omitted from the plate, and is given in the accompanying figure.

3

3. An enlargement of some of the branchlets of *Dendrograptus flexuosus.*

Formation and Locality.—Quebec group; Point Lévis.

DENDROGRAPTUS DIVERGENS, Hall. (n. s.)

Plate XVII, figures 3, 4.

Description.—A fragment of a frond of this species shows a flexuous stipe of moderate strength, with slender bifurcating branches, the divisions numerous and widely diverging: cellules arranged in alternating order on the opposite margins of one face of the stipe; non-celluliferous face very obscurely striated.

This species differs from all the others in its regular bifurcation, and in the wide divergence of the branches. The specimen is extremely compressed, and the cellules are only determined by indentations in the shale. It occurs in the same shales with *D. erectus*, *Graptolithus Logani*, *G. quadribrachiatus*, *G. denticulatus*, *G. arcuatus*, *G. Bigsbyi*, and others.

EXPLANATION OF FIGURES OF DENDROGRAPTUS DIVERGENS, Hall.

PLATE XVII.

3, 4. A specimen of natural size, and an enlargement of the same.

Formation and Locality.—Quebec group; Point Lévis.

DENDROGRAPTUS STRIATUS, Hall. (n. s.)

Plate XVII, figures 5–6.

Description.—Frond numerously branched, spreading. Stipe below the branches unknown. Branches cylindrical, tubular, substance thick and strong: branches and branchlets moderately diverging; non-celluliferous side finely striated longitudinally; striæ continuous, gently undulating. Celluliferous face striated: cellules minute, arranged in an alternating series, or in an undulating line, upon one face of the branches. The indentations left in the shale give an appearance as of a single linear range of cellules. Cellules in the proportion of thirty-six to an inch.

This species is readily distinguished by its striated surface. In mode of branching it resembles *D. erectus;* but differs in the striæ, and in having cellules on the lower part of the branches. The specimen is in a greenish-olive shale.

EXPLANATIONS OF FIGURES OF DENDROGRAPTUS STRIATUS, Hall.

PLATE XVII.

5. A fragment of a frond, preserving the bases of some of the branches.
6. A portion of the non-celluliferous surface enlarged.

Formation and Locality.—Quebec group; Point Lévis.

DENDROGRAPTUS ERECTUS, Hall. (n. s.)

Plate XVII, figure 7.

Description.—Stipe strong, elongated, erect, nearly straight. Branches alternate, ascending, and causing at their offset a slight bending or divergence of the stipe: branches bifurcating, branchlets alternating; all very slightly spreading, the stipe maintaining a greater diameter than the branches as far as the eighth bifurcation (in the specimen), beyond which it is broken off. Cellules visible on the branchlets only as slight expansions, causing an undulation on the margins, and in the impressions causing slight indentations on the surface of the matrix. Surface of the stipe and lower part of the branches entirely smooth under an ordinary lens.

This species differs from all others of the collection in the elongated and nearly straight stipe, which maintains its distinction from the branches for a long distance above the base. It differs from the strong stipes of *D. fruticosus* in the almost regularly alternating branches, which are distantly and somewhat equally bifurcated. The stipe appears to have been a strong cylindrical tube of dense corneous texture, and the lower part of the branches have the same character. The compressed specimen is marked along the middle of both sides by a longitudinal groove, which appears to have been produced by the flattening of the stipe. The total absence of striæ, and apparently of cellules, on the stipe and lower part of branches, together with the very slight divergence of the branches, are features peculiar to this species. It occurs in the same association as *D. divergens*.

EXPLANATION OF FIGURE OF DENDROGRAPTUS ERECTUS, Hall.

PLATE XVII.

7. The principal stipe, and bases of some of the branches, of the natural size.

Formation and Locality.—Quebec group; Point Lévis.

Dendrograptus fruticosus, Hall. (n. s.)

Plate XVII, figures 8, 9.

Description.—Frond robust. Stipe strong, rounded below, and sometimes terminating in a root-like expansion, flattened above, and irregularly bifurcating; the branches frequently subdivided, the bifurcations continuing almost to the extremities. Branches and branchlets somewhat rounded and undulating or zigzag in direction, smooth or indistinctly striated on the non-celluliferous side. Cellules in alternating series on the opposite margins of the celluliferous side, and distant about twice the width of the branch; from about thirty-three to thirty-six in the space of an inch; swelling out towards the apertures, and giving the undulating appearance to the branches. Cell-denticles angular or sub-angular, twice as long on the lower slope as on the upper or aperture side. The cellules make an angle with the axis of apparently between 25° and 35°.

This species is abundant in the coarse shales which contain *Phyllograptus typus.* The general aspect is that of a delicate plant, and it requires careful observation to detect the celluliferous character of the branches; the celluliferous side also more frequently adheres to the stone. In the impressions thus left after the removal of the substance of the branch, as well as upon the branches themselves, we see the cellules arranged on the margins in alternating series, but with the apertures opening on the same side.

Whenever the pressure has been upon the non-celluliferous side, and that side is exposed, the evidence of cellules consists of little more than enlargements of the sides of the branches. When a stipe is turned a little on one side, a row of cellules becomes visible; and a further turning of the branch discloses the two series, or the alternating ranges of cellules. The form of the cell-denticle is much influenced by the direction of the pressure upon the branches, and also by the character of the surrounding matrix. The root-like expansion at the base does not appear to have been more solid than the stipe above, and is in appearance not unlike the central discs of the uniserrate graptolites.

Explanations of Figures of Dendrograptus fruticosus, Hall.

Plate XVII.

8. A frond which is apparently nearly entire.
9. A more diffuse form of the same species, with some of the branches broken off.

Formation and Locality.—Quebec group; Point Lévis.

DENDROGRAPTUS ? (CALLOGRAPTUS ?) DIFFUSUS, Hall. (n. s.)

Plate XVIII, figures 1–3.

Description.—Stipe strong, rigid, gradually decreasing in width at each bifurcation: bifurcations numerous, irregular, the stipe slightly bending at each division, and the branches and branchlets strongly diverging. Substance of the fossil extremely compressed, obscurely corrugated; celluliferous face flattened. Cellules apparently arranged in a single series along the longitudinal centre of the branches in the form of minute indentations, and leaving similar minute pustuliform marks in the impressions of the branches; cellules about thirty-six in the space of an inch.

This species differs from *D. erectus* in the more rigid and more widely diverging branches. It occurs in a dark colored or nearly black shale, associated with *Graptolithus extenuatus*, *Climacograptus antennarius*, *Retiograptus tentaculatus* and *Retiolites ensiformis*.

EXPLANATIONS OF FIGURES OF DENDROGRAPTUS ? (CALLOGRAPTUS ?) DIFFUSUS, Hall.

PLATE XVIII.

1. A portion of a broken frond from near the base. The test is removed in some parts, showing celluliferous markings.
2. A fragment of another specimen with similar cell-markings.
3. An enlargement, showing the cell-apertures. The specimens are extremely compressed.

Formation and Locality.—Quebec group; Point Lévis.

DENDROGRAPTUS GRACILIS, Hall. (n. s.)

Plate XVIII, figures 5, 6.

Description.—Frond diffuse, numerously branched. Branches very slender, extremely elongate and sub-pendulous, celluliferous on one side; the cells are arranged in an apparently sub-alternate order, or have assumed this order during the compression of the specimen. Surface striated: cellules deeply indenting the margin of the branchlet, and the outer margin furnished with a mucronate extension.

This species is well marked by its extremely slender branches, which are distinctly serrated, while one side is strongly striated, and the deep indentations give a semi-articulate character to the branches.

Several fragments of this species have been found associated with *Callograptus elegans* and *C. Salteri*, but none more nearly entire than the specimen figured.

EXPLANATIONS OF FIGURES OF DENDROGRAPTUS GRACILIS, Hall.

PLATE XVIII.

5. Two of the larger branches with their sub-divisions, of the natural size.
6. An enlargement from one of the branchlets, showing the striate surface and the deep indentation of the cellules.

Formation and Locality.—Shales of the Quebec group; Point Lévis.

GENUS CALLOGRAPTUS, Hall. (n. g.)

Gr. *καλλος, pulcher*, and *γραφω, scribo.*

Generic characters.—Flabellate fronds, with numerous slender bifurcating branches proceeding from a strong stem or axis. Branches and divisions celluliferous on one side, the opposite side striate; sometimes distantly and irregularly united by transverse dissepiments. The non-celluliferous side sometimes presents a semi-reticulate appearance.

The aspect of these fronds is intermediate between *Dictyonema* and some forms of *Dendrograptus;* but they have not the regular reticulate structure of the former, while the sub-divisions of the branches are quite similar to some of the species of that genus. In the mode of branching and the form of cell-apertures, the present genus is quite different from the typical species of *Dendrograptus.*

The slender branches and minute points which indicate the cell-apertures render it impossible, with the specimens in my possession, to determine satisfactorily the characters of the latter: they appear as simple oval impressions upon the surface of the compressed branches.

It is possible that some of the species of this genus may have grown in funnel-shaped fronds, as *Dictyonema.*

CALLOGRAPTUS ELEGANS, Hall. (n. s.)

Plate XIX, figures 1–4; and Plate XVIII, figure 4.

Description.—Frond broadly flabelliform. Stipe short, flexuous, swelling at the base or root. Branches originating near the root, becoming numerously subdivided, the divisions slightly diverging or nearly parallel, while the whole expands to a somewhat semi-circular form when entire. After the second or third bifurcation the branches become very slender, and continue of nearly equal width. Non-celluliferous face strongly striated, slightly swelling at the cellules: celluliferous face striated; the cellules arranged alternately on the opposite margins, parallel or slightly diverging, and opening in a projecting process or cell-denticle, of undetermined form.

This species differs from *Dendrograptus fruticosus* in its more regularly-branching habit, less divergence of branches in mature specimens, shorter stipe, and more regular flabellate form. It differs from *D. flexuosus* in the more numerous, more slender, and less diverging branches and branchlets. From both it differs in the form of the cells, and in the strongly-striated non-celluliferous face of the frond. In young individuals the branches are often much more divergent, but the striated surface and the arrangement of the cellules correspond in all.

The specimens of this species occur in a fine grayish slate, associated with *Graptolithus nitidus*, *G. constrictus*, *G. bryonoides*, and *G. octobrachiatus*.

EXPLANATIONS OF FIGURES OF CALLOGRAPTUS ELEGANS, Hall.

PLATE XIX.

1. A fragment of a frond, natural size.
2. A nearly entire flabelliform frond. The two shaded lines running nearly vertically through the figure, are due to faults or slips in the slate, causing a slight overlapping of the laminæ, and an interruption of the continuity of the frond.
3. An enlargement, showing the lateral connection of the branches at irregular intervals.
4. A further enlargement of the non-celluliferous side of a bifurcating branchlet, showing the striated surface and a semi-articulate structure.

PLATE XVIII.

4. A fragment which is more lax and spreading, with shorter branchlets than the ordinary specimens, but having similar striæ, and a similar arrangement of cellules.

Formation and Locality.—Quebec group; Gros Maule.

Callograptus Salteri, Hall. (n. s.)

Plate XIX, figures 5–8.

Description.—Frond spreading or flabelliform above. Stipe below the branches and base, unknown. Branches numerous, undulating, bifurcating: divisions very little diverging; branches closely arranged, the space between them being usually less than the width of the branch. Non-celluliferous face smooth, or obscurely and interruptedly striate; celluliferous face with the cellules alternately on opposite margins, producing swellings of the branch at these points, and an undulating or tortuous direction. A few of the branches astomose, or an are sometimes connected by a short transverse bar of the same width as the branch. This does not appear to be a constant character.

This species has the same general form as *C. elegans*; but the branches are wider and less diverging, and obscurely or not at all striated. The zig-zag direction of the branches forms also a distinguishing feature. The stipe, which is not preserved in the specimens examined, was probably short, branching from near the base. This species occurs with *C. elegans* and its associated graptolites mentioned above.

Explanations of Figures of Callograptus Salteri, Hall.

Plate XIX.

5, 6. Fragments of two distinct fronds; one showing the celluliferous side, and the other the non-celluliferous side.

7. An enlargement from the non-celluliferous side, showing a few transverse dissepiments at irregular intervals. The figure has the same degree of enlargement as fig. 3 of *C. elegans*.

8. A farther enlargement of a bifurcating branchlet, showing the cell-apertures.

Formation and Locality.—Quebec group; Gros Maule.

Genus DICTYONEMA, Hall.

Gr. δικτυον, *rete*, and νημα, *filum*.

(Dictyonema, Pal. N. Y., vol. ii, p. 174, 1852, and *Geol. Survey of Canada*, Report for 1857, p. 142. Graptopora, Salter, Proc. Amer. Assoc.; Montreal, 1857.)

Generic characters.—Fronds consisting of flabelliform or funnel-shaped expansions (circular from compression), composed of slender radiating branches, which frequently bifurcate as they recede from the base. Branches and subdivisions united laterally by fine transverse dissepiments; exterior of branches strongly striated and often deeply indented; inner surface celluliferous or serrate, as in *Graptolithus*.

The general aspect of the species of this genus is like that of *Fenestella*, both in the form of the fronds and bifurcation of the branches. Some of the species have heretofore been referred to that genus, and others to *Gorgonia*. They may be known from either of these genera by the striated and serrated corneous skeleton, and by the absence of round cellules; which latter character, with a calcareous frond, marks *Fenestella*.

Dictyonema irregularis, Hall. (n. s.)

Plate XX, figures 1, 2.

Description.—Frond spreading, diffuse. Branches lax, frequently bifurcating; bifurcations unequal; branches equal to one half the usual width of the interspaces, or a little less; connecting filaments generally slender, expanding at their junction with the branches. Fenestrules extremely irregular in form and proportions, varying from a width greater than the length, to a length three or four times as great as the width; those with a length and breadth nearly equal, often appear hexagonal. Near the base of the frond, the fenestrules are sometimes elongate and triangular. Cellules undetermined. Surface without distinct organic markings. Branches arranged in the proportion of from twenty-five to twenty-eight in the space of an inch.

This species is much smaller than either of the others, scarcely equalling in dimensions the *D. gracilis* of the Niagara group, from which it differs in its more irregular form and diffuse habit. In one specimen there appear to be some identations upon the stone, indicating minute cellules, but they are too obscure for satisfactory determination. This species has been seen only in small fragments: the entire frond is unknown.

EXPLANATIONS OF FIGURES OF DICTYONEMA IRREGULARIS, Hall.

PLATE XX.

1. A fragment from near the base of a frond.
2. A fragment from the outer portion of the frond.

Formation and Locality.—Quebec group ; Point Lévis.

DICTYONEMA ROBUSTA, Hall. (n. s.)

Plate XX, figures 3, 4.

Description.—Frond large, spreading, extremely robust. Branches wide, strong, bifurcating: bifurcations slightly diverging, the interspaces about the same width as the branches. Fenestrules large, elongated; the length from seven to nine tenths of an inch, and the breadth from one twelfth to one seventh of an inch. The transverse connecting filaments comparatively slender: cellules not determined. Surface smooth or obscurely striate.

The specimens of this species before me do not admit of a more complete diagnosis than that above given. It differs from any other species known to me in the great strength of the branches, and in the very elongate fenestrules; while the dissepiments or connecting filaments are usually comparatively slender. The divisions of the branches diverge but little, and the frond does not appear to have been abruptly expanded. It occurs on the hard shales with *Graptolithus rigidus.*

EXPLANATION OF FIGURES OF DICTYONEMA ROBUSTA, Hall.

PLATE XX.

3, 4. Fragments of two different fronds. In some parts of the specimen fig. 3, and in all of fig. 4, the branches are extremely flattened and attenuate.

Formation and Locality.—Quebec group : Point Lévis.

Dictyonema quadrangularis, Hall. (n. s.)

Plate XX, figure 5.

Description.—Frond large, robust. Branches linear, nearly parallel, rarely bifurcating: branches about five hundredths of an inch in width, the interspaces having an average width of eight hundredths of an inch. Fenestrules quadrangular, length and breadth usually nearly equal: connecting filaments nearly as wide as the branches, expanded at their junction with the latter, so as to give an apparent sub-hexagonal form to the fenestrule. Cellules not determined. Surface free from any characteristic markings.

This species is very distinct from the two preceding, and from nearly all other species, by the almost parallel direction of the branches. A fragment an inch and a quarter wide by three inches long, shows not more than four or five bifurcations. The apparently hexagonal form of the fenestrules may be due in part, or entirely, to the breaking or wearing away of the margins of the stipes, or of the connecting filaments, or of both. The short equilateral fenestrules form the most prominent and characteristic feature. It occurs with the other species just described, and with *Graptolithus rigidus*, in the same hard shales.

Explanation of Figure of Dictyonema quadrangularis, Hall.

Plate XX.

5. A fragment of a frond, of natural size.

Formation and Locality.—Quebec group; Point Lévis.

Dictyonema Murrayi, Hall. (n. s.)

Plate XX, figures 6, 7.

Description.—Frond very large, gradually spreading from its origin. Branches strong, width from five to eight hundredths of an inch, infrequently bifurcating; divisions little diverging, the interspaces being little wider than the branches. The fenestrules have a width of eight by a length of eleven hundredths of an inch. The connecting filaments are wide at

their origin or union with the branch, and slender in the middle; from about one third to one half as wide as the branches. Cellules undetermined. Surface smooth.

This species is associated with *D. robusta.* It is a less robust form, the branches are not more than one half as wide, and the fenestrules not more than one third the length of those in that species, while the connecting filaments are quite as strong. The specimens are extremely compressed, and the character of the cellules cannot be determined.

While the preceding species all have the characteristics of true *Dictyonema*, in none of them has the base been discovered, and the entire form of the frond is therefore unknown. From the strong growth of all of them, and the nearly parallel direction of the branches, we must presume them to be fragments of very large fronds.

Explanation of Figures of Dictyonema Murrayi, Hall.

Plate XX.

6, 7. Fragments of two fronds; the figures of the natural size.

Formation and Locality.—Quebec group; Point Lévis.

Genus PTILOGRAPTUS, Hall. (n. g.)

Gr. πτιλον, *pluma*, and γραφω, *scribo*.

Generic characters.—Frond plant-like, rooted? simple or branching. Branches and branchlets plumose, the pinnules rising alternately on opposite sides of the branches; celluliferous on one face only: branches cylindrical or flattened. Substance corneous, dense; apparently smooth exteriorly, or corrugated by compression, or during fossilization.

In general habit this genus resembles the modern *Plumularia*, and its mode of growth was probably similar. We know at the present time two species, one a slender and delicate form, the other more strong and coarse, and differing in its irregular mode of branching; while at the same time the smaller branches and pinnulæ resemble the other species. The cellules are distinctly confined to one face of the pinnulæ; but whether arranged in a single linear series, or in alternating order, cannot be satisfactorily determined. Both species are in soft shales, associated with *Graptolithus Logani*, *G. quadribrachiatus*, *G. arcuatus*, *G. Bigsbyi*, and others.

Ptilograptus plumosus, Hall. (n. s.)

Plate XXI, figures 1–4.

Description.—Frond bi-pinnate, branching. Branches slender, plumose; the axis round and smooth on the non-celluliferous side, and grooved on the opposite side. Pinnules simple or rarely divided, alternate, long and slender, flexuose, rising at an angle of 40° to the axis. Cellules minute, arranged upon one face of the pinnules.

The entire form of this species is unknown: the branches appear to have been rounded, solid, and very gradually tapering. The pinnulæ are slender, linear, maintaining their width to the obtuse extremities: they have sometimes a length of about five eighths of an inch. Near the base they are solid; beyond this they are flattened and slightly rugose (as if from contraction), and preserve very little substance. It has not yet been satisfactorily determined whether the cellules are arranged in a single linear series on one side of the pinnulæ, or in a double alternating series.

Explanations of Figures of Ptilograptus plumosus, Hall.

Plate XXI.

1. A fragment which is three times branched.
2. A slender simple branch.
3. An enlargement from the specimen fig. 1.
4. A further enlargement of a portion of the same; some of the branches showing markings like cell-apertures.

Formation and Locality.—Shales of the Quebec group; Point Lévis.

Ptilograptus Geinitzianus, Hall. (n. s.)

Plate XXI, figures 5–8.

Description.—Frond numerously and irregularly branched. Branches thick and strong, irregularly bifurcating. Pinnulæ broad and strong, closely alternating on opposite sides of the branches. Cellules large, arranged on one face of the pinnulæ: non-celluliferous side smooth, or corrugated from compression.

This species differs from the preceding in its stronger and coarser habit, its more frequent and irregular branching, in the broad flattened branches and the broader pinnulæ, of which there are about six in the space occupied by nine in the other species. The cellules are stronger, and apparently more distant.

Explanations of Figures of Ptilograptus Geinitzianus, Hall.

Plate XXI.

5. A branching fragment showing the celluliferous side.
6. A fragment which is irregularly branched, showing the non-celluliferous side.
7. A single branchlet of the same species.
8. An enlargement from fig. 5, showing the cell-apertures.

Formation and Locality.—Shales of the Quebec group; Point Lévis.

Genus THAMNOGRAPTUS, Hall.

Gr. *θαμνος, frutex,* and *γραφω, scribo.*

(Thamnograptus, Pal. N. Y., Vol. III, p. 519,* 1859.)

Generic characters.—Fronds consisting of straight or flexuous stipes (growing singly, or conjoined in groups at the base?), with alternating or widely diverging branches: branches long, simple or ramose, in the same manner as the stipe. Substance fibrous or striate; the main stipe and branches marked by a central longitudinal, depressed line, indicating the axis. Cellules or serratures unknown.

Thamnograptus Anna, Hall. (n. s.)

Plate XXI, figure 9.

Description.—Stipes slender, linear, undulating. Branches filiform, long, flexuous, regularly alternating on opposite sides: the distance between the branches on the same side is about fifteen hundredths of an inch, giving half that distance on the main stipe between the origin of the branches. At the base of each branch, the stipe diverges in the opposite direction, making an angle of 30° with its previous direction. The angle between the stipe and the branch measured on the lower side is about 130°, and on the upper side 80°, showing a divergence of 30° in the direction of the stipe.

* A description of this genus, with other graptolitic genera, was read before the American Association for the Advancement of Science, at Baltimore in 1858; but the paper was not sent in for publication, and only a newspaper report of it was given.

The branches are flexuous, filiform, and as far as traced, simple ; rounded or somewhat flattened as they occur in the stone. The substance of the stipe or branches does not show cellules ; and the markings are groove-like depressions in the stipe for a short distance below the base of the branches. The test is corneous, black and shining.

This species differs from *T. typus* of New-York, in its less rigid appearance, flexuous stipe, and more diverging branches.

EXPLANATION OF FIGURE OF THAMNOGRAPTUS ANNA, Hall.

PLATE XXI.

9. A fragment of the species, of the natural size.

Formation and Locality.—Quebec group ; three miles above the mouth of the river Ste. Anne.

SUPPLEMENT.

DESCRIPTIONS OF SPECIES FROM THE UTICA SLATE, INTRODUCED FOR COMPARISON AND ILLUSTRATION.

GRAPTOLITHUS FLACCIDUS, Hall. (n. s.)

Plate II, figures 17–19.

Description.—Frond consisting of two slender linear flexuous stipes, which are widely divergent from a small short obtuse radicle. The stipes at their origin are gently ascending, and then curve broadly backwards or downwards, and maintain throughout their entire length a curvilinear direction; stipes cylindrical near the base, and flattened in their extension. Surface smooth, or with striæ so fine as to be invisible under an ordinary lens. The diameter of the stipe varies from two hundredths near its origin, to four hundredths of an inch in the fully-developed parts, maintaining this width to the extremity: more than one half of the width is occupied by the common body. Test comparatively thick. Cellules narrow; from twenty-eight to thirty and near the base sometimes thirty-two in the space of an inch; inclined at an angle of 20° or less to the direction of the axis. Point of the denticle or aperture obtusely rounded, very rarely angular: cellules free throughout their entire length.

This is a very distinct and well-marked species, with slender lax stipes extending four or five inches or more from the radicle. It occurs in large

numbers, the stipes lying intertwined among themselves upon the surface of the shale. The cell-denticles are very minute; and near the base of the stipe the surface appears as if marked by small punctured or indented pustules. This pustuliform aspect seems to be due to the strong partition-walls of the cellules, which resist the pressure, and retain nearly their original form, while the adjacent parts become flattened. Farther from the origin of the stipe the whole substance is extremely compressed, and the cellules are only indicated by undulations in the margin of the stipe, which show obscurely the rounded cell-denticle. The cellules are almost always upon the convex side of the curve of the stipe.

The proportions of the stipe are about the same as in *G. tenuis*, Hall, (not Portlock); but that species has the stipes straight and extremely flattened in all the specimens seen. In both species the cell-denticles are rounded, or appear only as slight undulations of the margin; but in *G. tenuis*, the number in the space of an inch is from twenty-two to twenty-four. These, with the other differences, are very distinctive.

Explanations of Figures of Graptolithus flaccidus, Hall.

Plate II.

17. A portion of a large fragment of slate, with parts of several individuals upon the surface, and showing the origin of eight individuals in the minute radicles. Some of these are indicated by asterisks on the engraving.
18. An enlargement to three diameters of the radicle and stipe-bases, with the cellules. From the point *a* on fig. 17.
19. A farther enlargement of a portion to show the form of the cellules, and the pustuliform appearances at the base of the divisions between the cellules.

Formation and Locality.—Shales of the Utica formation; Lake St. John, east from Blue Point.

Graptolithus quadrimucronatus, Hall. (n. s.)

Plate XIII, figs. 1–10.

Stipes consisting of simple quadrilateral tubes, which are celluliferous on the two opposite sides; the plain and the celluliferous sides being of equal width in the middle, or half-way from the base to the apex, where the stipe attains its greatest dimensions; celluliferous sides of the stipe

gently increasing in width from the base, with the sides parallel above. The base is narrow and somewhat obtusely pointed below. In what appear to be mature stipes the greatest length is two and a half inches; the width, when flattened and showing two of the four sides, is a little more than one eighth of an inch, exclusive of the cell-denticles. Test corneous, comparatively thick, and without visible striæ. A slender axis marks the centre of the stipe, and rarely extends beyond the apex. The cellules consist of simple notches or transverse slits in the opposite sides, which are slightly indented in the non-celluliferous face, and each angle or sinus produced into a slender, mucronate spine, making a range of spines upon each angle, or four ranges of spines marking the entire length of the stipe; about twenty-two cellules in the space of an inch, the margin or lip slightly projecting.

The specimens of this species occur in great numbers upon the weathered and fresh surfaces of some specimens of the Utica slate. Some are in a well-preserved condition, others are partially preserved, and others consist of moulds or impressions of the stipes. The specimens have been compressed in every possible direction, sometimes parallel to the celluliferous face, giving the more natural expression, or that which is regarded as the more characteristic of the graptolite (fig. 1); others are compressed vertically to the celluliferous sides, so that the plain faces are pressed beyond the margins of the cellules, giving the scalariform character (fig. 3). In other specimens the pressure has been directed against the angles of the stipe, showing one of the plain, and one of the celluliferous sides (fig. 2). The cellules in such examples extend half way across the width of the stipe, and show the spines upon the outer margin; while the spines marking the inner margin are either compressed or broken off (fig. 8), leaving their bases visible along the centre of the stipe. On the opposite margin the mucronate spinules, marking the inner angle of the opposite cellules, are shown, extending outward as far as those on the opposite side, though that half of the stipe is entirely plain with an undulating margin between the spinules. Sometimes on this side the spinules may be folded beneath, and the stipe presents a continuous margin, and has the appearance of a uniserrate graptolite, both characters being sometimes seen in the same individual (fig. 2).

In specimens which are compressed vertically to the non-celluliferous face, the mid-rib or axis is distinctly marked, often throughout the entire length of the individual, as a slender filiform body. The cell-partitions in some specimens are well marked, but in the greater number are obscure; this condition probably arising from the thick outer test of the specimen. The spinules originate in the sinus or angle at the intersection of the lip of the aperture with the body of the stipe.

Some other species besides this have grown as quadrilateral tubes. Those specimens which show an undulated margin with projecting mucronate points or spinules can be of no other form than that which is here described: we have good reason to suppose all those with inequilateral stipes to belong to the same form; and those with deep indentations on one side and without cell-markings, except simple undulations on the other side, are only another phase, depending upon the direction and degree of pressure.

The species under consideration, in its various aspects, illustrates more fully than any other which we have seen, the effects of pressure in different directions. The cellules, in form and in manner of opening upon the surface, differ from such as *Graptolithus pristis*, and appear to be intermediate between those of *G. bicornis*, = *Climacograptus*, and those of *G. ramosus*.

Explanations of Figures of Graptolithus quadrimucronatus, Hall.

Plate XIII.

Fig. 1. Part of a stipe compressed in a slightly oblique direction, still showing the cellules on the two sides.

Fig. 2. A stipe compressed more obliquely, so as nearly to obscure the cellules on one side.

Fig. 3. A specimen compressed vertically to the celluliferous side of the stipe.

Figs. 4, 5, and 6. Enlargements from specimens, figs. 1, 2, and 3 respectively.

Fig. 7. Enlargement from a specimen where the solid axis lies near to one side.

Fig. 8. A specimen obliquely compressed, so that the mucronate points at one angle of the cellules of the left side, are pressed through the test, and show on the surface as a range of pustules. The axis is displaced, and seen on one side of the centre.

Fig. 9. A diagram representing a theoretical longitudinal section.

Fig. 10. A transverse section of a stipe with the mucronate extensions of the cell-margins.

Formation and Locality.—Utica slate formation; Lake St. John, east from Blue Point.

Reteograptus eucharis, Hall. (n. s.)

Plate XIV, fig. 9.

Frond spreading, nearly flat, consisting of numerous narrow lanceolate elliptical stipes, attached to a common initial point or axis, and bilaterally arranged on two sides of a short funicle, which is four or five times bifurcated on each side.

Stipes varying in proportions, the length being from three to five times the width; axis very distinct, undulating, and its continuation traced from the radicle to the distal extremity, beyond which it extends in a mucronate point. Cell-partitions distinct, alternating, essentially rectangular to the axis, the cellules having their greatest development about the middle of the length of the stipe. Margins of the stipe ornamented by short mucronate points which alternate with the cell-partitions.

Surface of the test smooth or granulose.

Explanation of Figure of Reteograptus eucharis, Hall.

Plate XIV.

Fig. 9. The frond three times enlarged.

Formation and Locality.—Utica slate; Blue Point, Lake St. John.

INDEX.

PLATES.

Plates A and B illustrate the structure of the Graptolitidæ as referred to in the Introduction, Chapter I.

Plates I to XXI illustrate the species of Graptolitidæ described in Chapter II and Supplement.

EXPLANATIONS OF PLATE A.

Climacograptus typicalis, page 57.

See observations on *C.* (*G.*) *bicornis*, etc., pages 27, 28, 30, 45, and 111.

Figures 1–8 are enlarged to six diameters.

Fig. 1. A lateral view of the concave side, with the surface entire, showing the form of the cell-apertures.

" 2. A lateral view of the same, showing the entire form of the cell-apertures.

" 3. Lateral view of a fragment where the surface is exfoliated, showing the cell-partitions extending downwards towards the centre.

" 4. A longitudinal section made a little below the exterior surface, showing the cell-partitions extending further towards the interior than in fig. 3.

" 5. A longitudinal section through the centre, showing the cell-partitions reaching to the central axis.

" 6. A transverse section, showing the cell-partitions just within the aperture, and the minute central axis.

" 7. A transverse section made a little lower than in fig. 6, showing the cell-partitions extending across the stipe on one side, and on the other side showing the narrow triangular point near the centre.

" 8. A section made diagonally across a crushed stipe, showing the folding (from pressure) of two cell-divisions on each side of the centre.

" 9. An ideal longitudinal section, showing the form and direction of the cell-partitions and the central axis, (enlarged to twelve diameters).

Graptolithus putillus, pages 27 and 44.

Enlarged to twelve diameters.

Fig. 10. A fragment of a stipe, showing the two ranges of cellules, their form, mode of growth, and the unfolding of the exterior test along the line of the central axis.

" 11. A lateral view of the same fragment, showing the cell-apertures and the flattening of the exterior of the base of the next cellules in advance, and the greater breadth of the cellules at the bases.

" 12. A longitudinal section through the centre of the stipe, showing the double cell-partitions and the double central axis.

" 12 *a.* A transverse section cutting one cellule near the aperture and the other near the base.

Climacograptus bicornis, pages 20, 21.

(*Graptolithus bicornis*, Palæontology of New York, vol. i, page 268, and Geology of Canada, page 200.)

Fig. 13. The lower part of a stipe enlarged to two diameters, showing the bifurcating process and a central node or radicle.

" 14. An enlargement to six diameters of a fragment which preserves in a very perfect manner the border of the cellules, and shows an undulating central axis as well as the median ridge.

" 15. The base of a specimen showing three spine-like processes, (two diameters).

" 16. The lower extremity of a specimen showing a partially developed corneous disc, (two diameters).

" 17. The lower extremity of another specimen, showing a more complete disc or bulb at the base, (two diameters).

EXPLANATIONS OF PLATE A, continued.

Climacograptus (sub-genus Dicranograptus) ramosus, pages 15, 31, 45, 46, and 112.

(*Graptolithus ramosus*, Palæontology of New York, vol. i, page 27, and Geology of Canada, page 200.)

Fig. 18. The lower part of a frond in which the base is entire, with the bifurcation above, (natural size).

" 19. The bifurcating portion, with a part of the simple stipe, showing the cells on one side as they are usually seen when flattened in the slate. On one portion of this there are oval pustules, which is a feature sometimes observed. The opposite side gives the appearance of the cellules when flattened and compressed partially against the aperture, (six diameters).

" 20. An enlargement from below the bifurcation, showing the more perfect form of the aperture, with the spines proceeding from the exterior surface above the aperture, (enlarged to six diameters); see page 31.

" 21. A young individual or germ, supposed to be of this species, showing the basal processes and the partially developed cellules at the upper part. See page 34.

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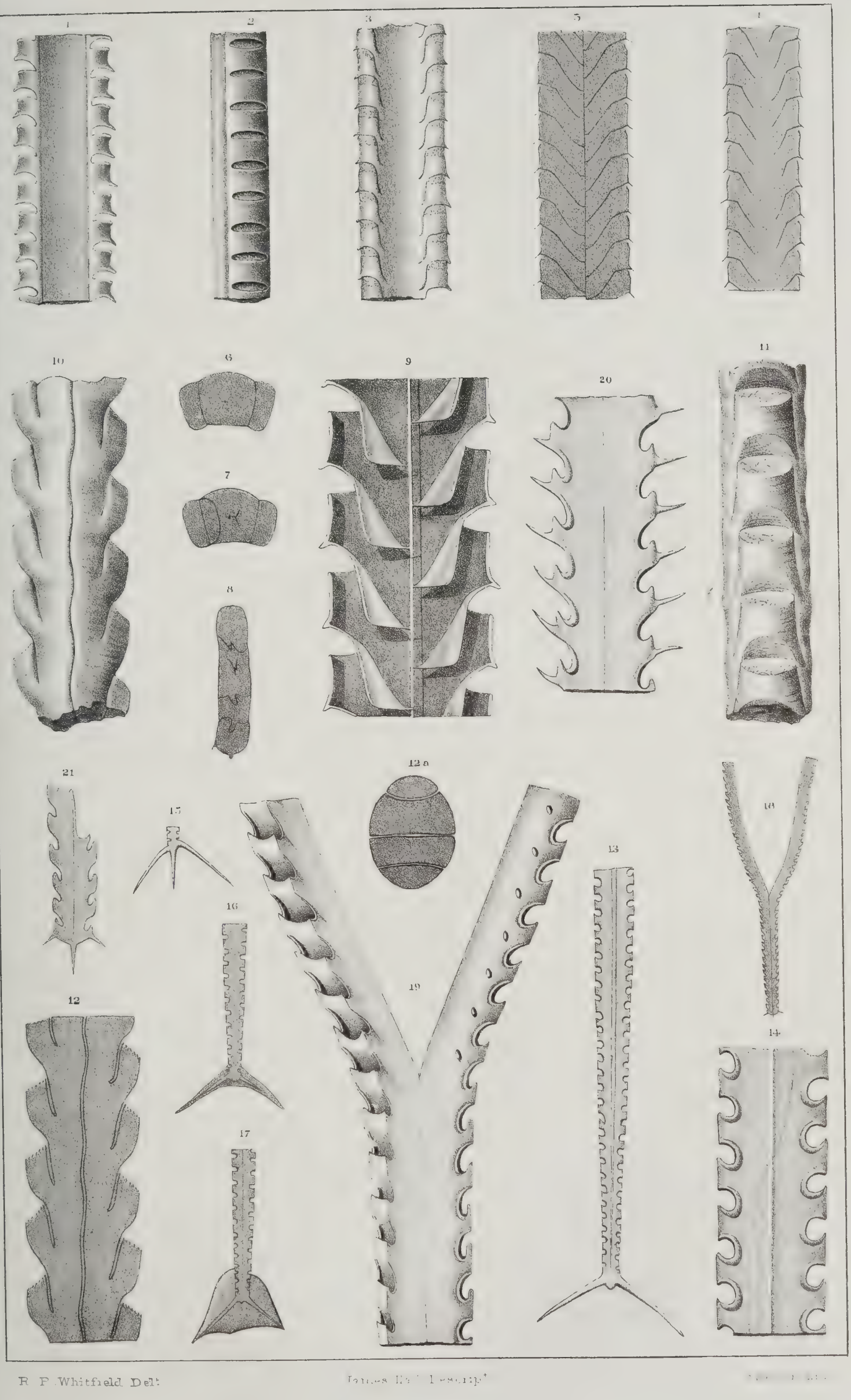
Decade 2. — Graptolitidæ. — Plate A.



R. P. Whitfield Delt.

James Hall Descript.

EXPLANATIONS OF PLATE B.

GRAPTOLITHUS CLINTONENSIS, pages 25, 27, 29.

(Palæontology of New York, vol. ii, page 39.)

Figures 1, 2, and 4 are enlarged to six diameters, and figure 3 to nine diameters.

Fig. 1. A fragment from near the base of a stipe, where the cellules are less developed than in other specimens. The cellules are partially filled with mineral matter and have an angular form.

" 2. A lateral view of a part of a mature stipe, showing the form of the cellules, and the recurved extremities causing the apertures to open downwards. The specimen is filled with mineral matter.

" 3. A front view of a part of the same stipe, showing the lateral extent of the cell-bases and the expansion at the aperture.

" 4. A dorsal view of the same, showing a groove which indicates the place of the solid axis.

" 5. A branch of DICTYONEMA GRACILIS (page 29), showing the serrated margin indicating cell-apertures; (enlarged six diameters).

GRAPTOLITHUS WHITFIELDI, pages 32, 33, and 36.

Figures 6 – 10 are of natural size; figure 11 is enlarged to two diameters.

Fig. 6. A stipe showing serratures, with a few partially developed reproductive sacs in the upper part.

" 7. A stipe where the sacs are more fully developed.

" 8. A stipe with numerous reproductive sacs, some of which have apparently become dehiscent, and exhibit numerous extremely slender fibres.

(In connection with one of these sacs there are two minute germs, one of them lying beneath the sac, and the other just beyond its outer margin and barely separated from its fibres. See fig. 11.)

" 9. A stipe with a few of the sacs remaining, and the bases of some others which have apparently been broken off. One of these sacs appears to be attached to the axis above the cellules and lying beneath the axis.

10. A stipe from which the reproductive sacs have been removed (by maceration), showing only the marginal fibres by which they were attached to the axis of the parent stipe. Some of these remain connected with the axis in its extension beyond the cellules.

" 11. An enlargement of a single sac, from fig. 8, showing the position of the two germs.

EXPLANATIONS OF PLATE B, continued.

Germs of Graptolites.

Figures 12, 13, 14, 16, 17, 18, 19, are germs of Graptolites enlarged to six diameters. (See pages 33 and 34.)

Fig. 12. A germ of a biserrate form, before the cellules have assumed distinctive shape. The axis is extended, and the common body spreads on both sides in the lower part, the cellules embracing the lateral processes, which are seen at the base of most of the diprionidian forms, and extending along one side of the axis above.

" 13. A form similar to fig. 12, a little farther advanced, where the lower cellules have begun to assume their proper form.

" 14. Another form of germ resembling *G. ciliatus;* the ciliated processes are visible beyond the limits of the sac, but the cellules appear not to have assumed definite form.

" 15. A young individual of *G. ciliatus*, (natural size).

" 16. A discoid germ. This may be the central disc of a compound form of Graptolithus.

" 17. A germ showing the common body extended on the two sides of the axis, but without any visible or apparent cellules.

" 18. A germ where the common body or sac is much expanded on the two sides of the axis, and the central portion is apparently becoming more solid.

" 19. A germ where the solid axis is on one side; the species probably belongs to the monoprionidian type.

Retiolites venosus, pages 22, 47, 113, and 114.

(Palæontology of New York, vol. ii, page 40.)

The figures are enlarged to nine diameters.

Fig. 20. The exterior of the convex (?) side, showing the external axis and cell-partitions, with the intermediate reticulate texture.

" 21. Another view, apparently from the interior (see page 47), showing an undulating or zig-zag axis, with cylindrical processes extending to the margins, and short, apparently broken processes directed obliquely upwards. The reticulate structure is not essentially different from that of the other side.

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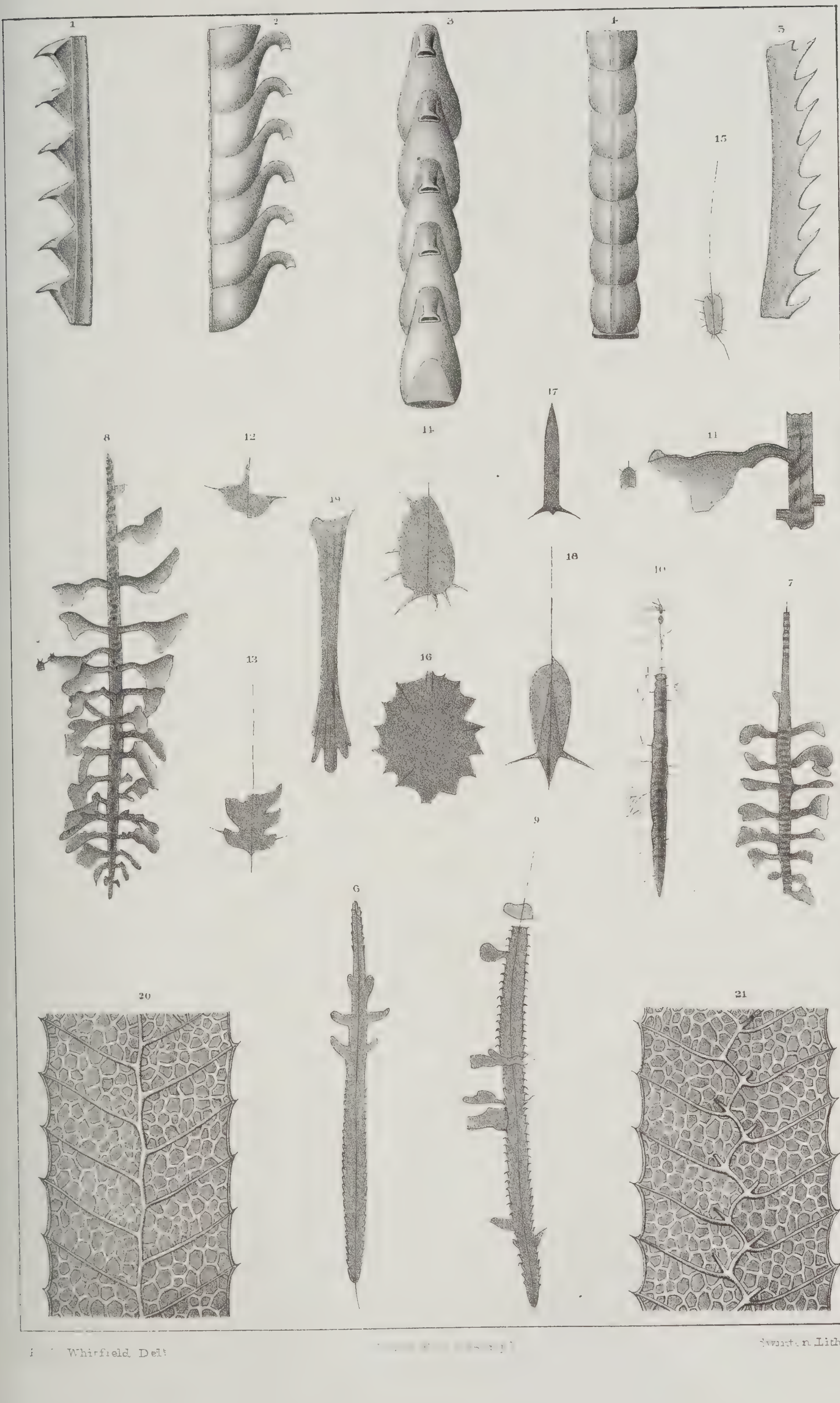
Decade 2. Graptolitidæ. *Plate B.*



Whitfield Delt — Swinton Lith.

EXPLANATIONS OF PLATE I.

Graptolithus nitidus, page 69.

Fig. 1. A young individual with the radicle and the two stipes.
" 2. The extremity of a stipe enlarged, showing the partially-developed cellules.
" 3. A larger specimen similar in character to fig. 1, showing the pustules at the base of the cellules. The extremities are not quite entire.
" 4. A part of the left side of fig. 3 enlarged, showing the pustuliform elevations.
" 5. An enlargement from fig. 8, with the cellules obliquely compressed and the pustules obscure.
" 6. Two smaller individuals, which, from juxtaposition and similarity, seem as if they may have originated from a common base.
" 7. An impression of a more extended form, proportionally narrower than fig. 3.
" 8. A still narrower stipe, diverging almost rectangularly from the direction of the radicle.
" 9. A well-preserved small individual, enlarged three diameters.

Graptolithus patulus, page 71.

Fig. 10. A specimen preserving the radicle, and a stipe on one side two and a half inches in length.
" 11. The distal extremity of a larger stipe. Some of the cells are filled with pyrites.
" 12. A short stipe broken off near the radicle, showing the narrow form near the base, and a width beyond greater than in ordinary forms.
" 13. A part of fig. 12 enlarged.
" 14. A part still further enlarged to show the striæ parallel to the cell-apertures.
" 15. An enlargement from fig. 11, where some of the cells are filled with iron pyrites showing their extension almost to the back of the stipe.

Graptolithus bifidus, page 73.

Fig. 16. A small specimen from the same fragment of slate with fig. 17.
" 17. An individual of ordinary size.
" 18. An enlargement of the upper part of one stipe of fig. 17.

Graptolithus indentus, page 74.

Fig. 20. An individual of the natural size, the continuation of the stipes having been broken off on ode side.

Graptolithus extenuatus, page 75.

Fig. 21. A fragment of the stipe, natural size.
" 22. A portion of the lower extremity enlarged ; a part of the specimen retaining the substance of the fossil, and a part being an impression in the slate.

Graptolithus constrictus, page 76.

Fig. 23. A young individual, natural size.
" 24. An older specimen, the stipe broken off on one side.
" 25. A part of a much more extended stipe, but which is not wider than fig. 23.
" 26. A part of a stipe from Gros Maule.
" 27. An enlargement of the last, showing the form of cells, the cell-denticles or apertures, and the characteristic apparent constriction.

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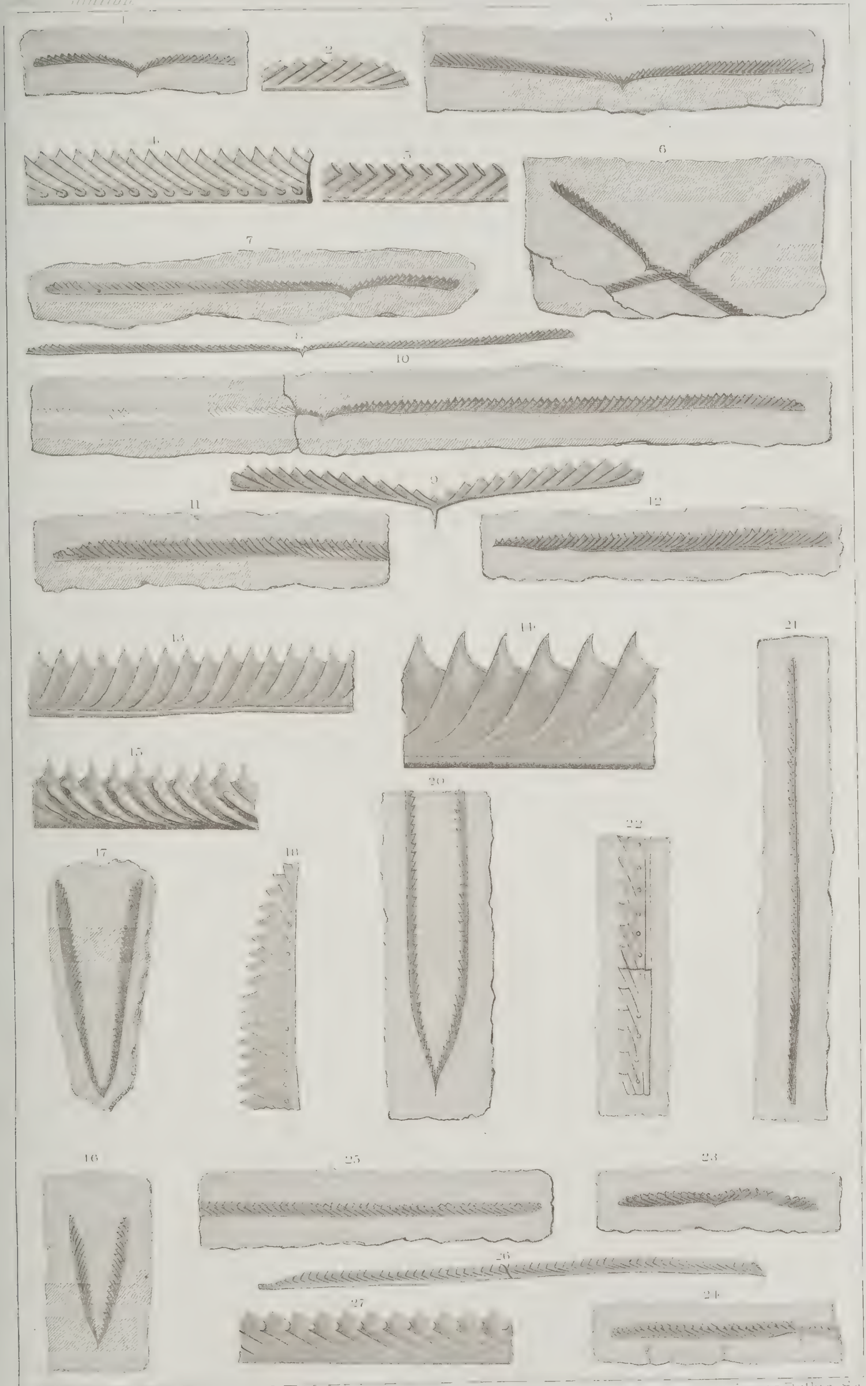
Decade 2.

Silurian

Graptolitidæ.

Quebec Gr.



R. P. Whitfield, Del.

James Hall, Descrip.

James Dulles, Sc.

EXPLANATIONS OF PLATE II.

Graptolithus similis, page 78.

Fig. 1. A very young individual of this species.
" 2. An individual somewhat more mature.
" 3. An enlargement showing the form of the radicle, and the cells near their origin, with a non-celluliferous space between.
" 4. A fragment of a longer stipe, which is imperfect at both extremities.
" 5. An enlargement of fig. 4.

Graptolithus arcuatus, page 79.

Fig. 6. A stipe of a small individual, more than usually curved.
" 7. A stipe having a process just above and opposite the radicle.
" 8. A larger stipe, the cellules very clearly preserved.
" 9. A specimen showing the stipes on both sides of the radicle, and preserving their peculiar curvature very perfectly.
" 10. An enlargement of a portion from figure 8.

Graptolithus extensus, page 80.

Fig. 11. A single stipe more than four inches long, with the radicle and base of the opposite stipe.
" 12. A fragment showing a part of the stipe on each side of the radicle, natural size.
" 13. The radicle and adjacent cellules, enlarged from fig. 12.
" 14. An enlargement of fig. 12 at a point about two inches from the radicle.
" 15. A fragment of a stipe where the cellules are distended by iron pyrites.
" 16. An enlargement from fig. 15.

Graptolithus flaccidus, page 143.

Fig. 17. A portion of a large fragment of slate, with parts of several individuals upon the surface; and showing the origin of eight individuals in the minute radicles. Some of these are indicated by asterisks on the engraving.
" 18. An enlargement to three diameters of the radicle and stipe-bases, with the cellules. From the point *a* on fig. 17.
" 19. A farther enlargement of a portion to show the form of the cellules, and the pustuliform appearances at the base of the divisions between them.

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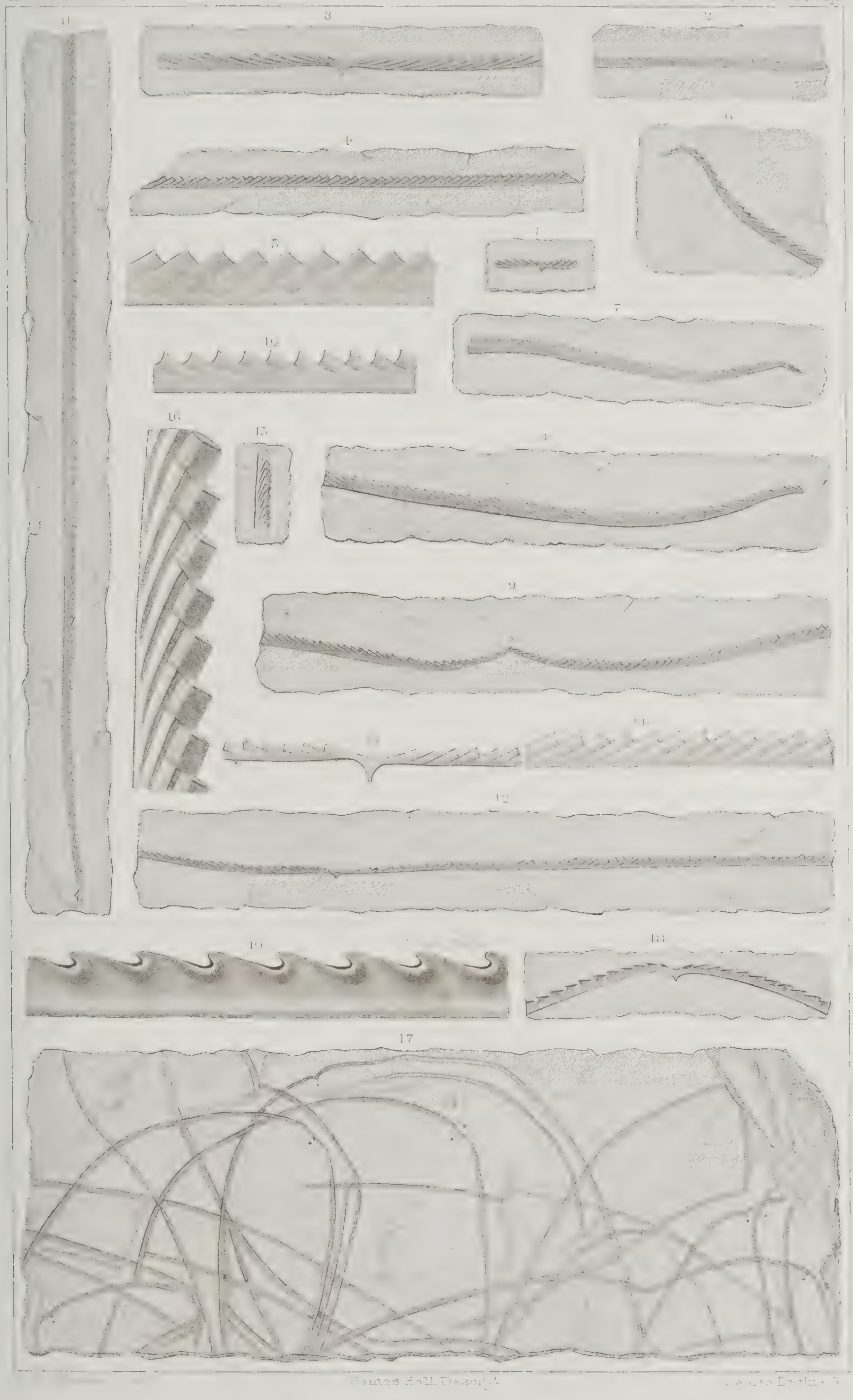
Decade 2. | Plate 2.
Lower Silurian. | Graptolitidæ. | Quebec Group.



James Hall Descript. | [illegible]

EXPLANATIONS OF PLATE III.

Graptolithus pennatulus, page 82.

Fig. 1. A young specimen with the minute radicle, the stipes diverging almost horizontally, or rectangularly to the radicle.
" 2. A young specimen with one stipe entire, and a part of the other, less diverging than fig. 1.
" 3. A single imperfect stipe of a young or half-grown individual, which is narrower than usual.
" 4. A larger stipe, which is entire from the base to the apex.
" 5. A large or full-grown single stipe, which is nearly entire.
" 6. An enlargement to three diameters from fig. 4, showing the form and proportion of the cellules, and cell-denticles.
" 7. An enlargement to the same degree as the preceding, from fig. 5.
" 8. A young specimen where the stipes are twisted near the base, giving an appearance as if the serrations were on the outer or lower side in relation to the direction of the radicle.

Graptolithus bifidus, page 73.

Fig. 9. An individual from the river St. Anne, showing a greater divergence of the stipes, which are wider than those from Point Lévis. (See plate i.)
" 10. An enlargement from one of the stipes of the preceding, showing the form of serratures, and the minute pustules at the base of the cell-divisions.

Graptolithus bryonoides, page 84.

Fig. 11. A fragment of a stipe from the rough shales containing *Phyllograptus ilicifolius.* In the character of the cell-denticles it resembles the specimen pl. iv, fig. 9 and with that one may constitute a distinct species.
" 12. An enlargement of a part of the specimen fig. 11.

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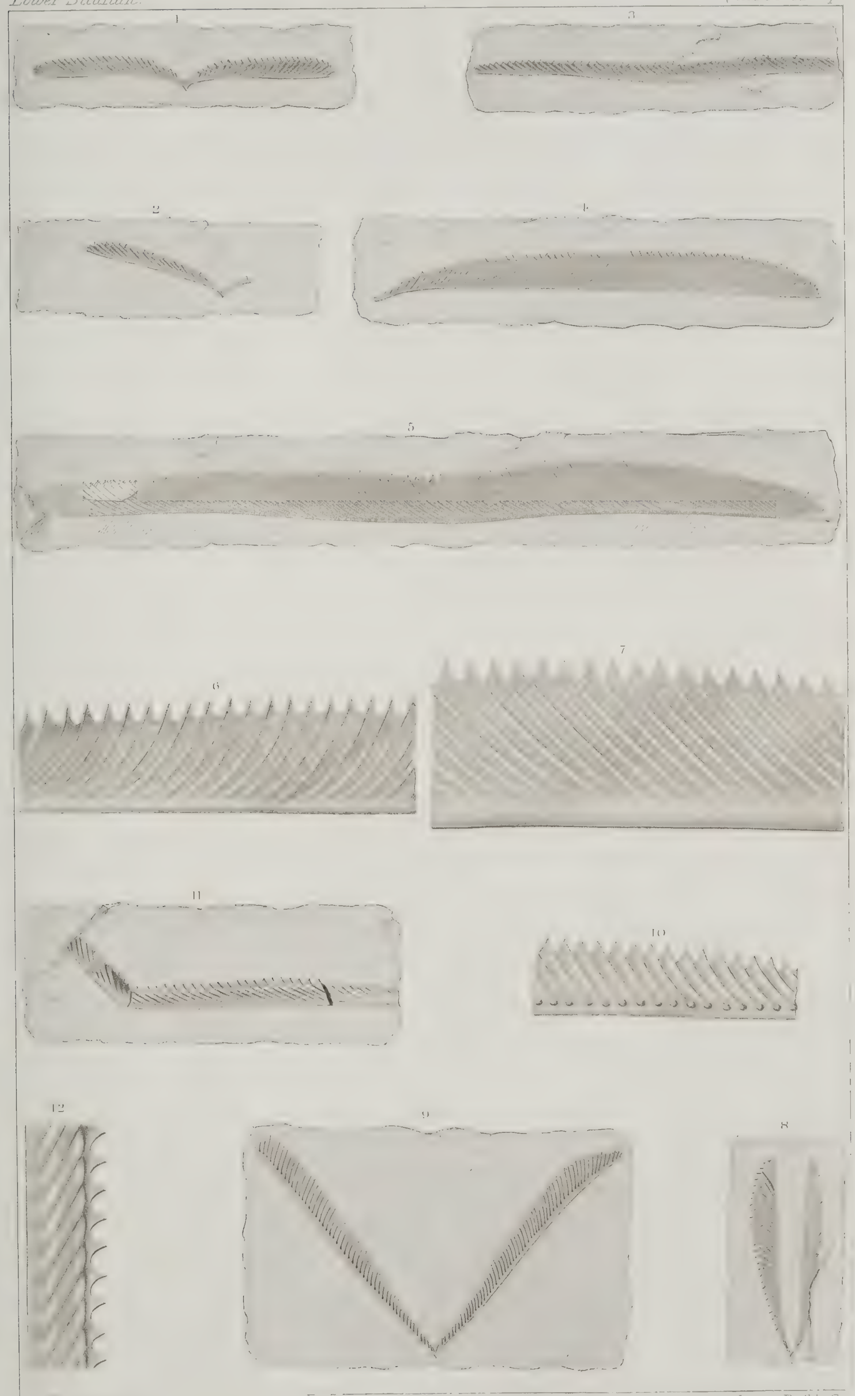
Decade 2.
Lower Silurian.

Graptolitidæ.

Plate 3.
Quebec Group.



James Hall, Descrp.t

James Duthie, Sc.

EXPLANATIONS OF PLATE IV.

GRAPTOLITHUS BRYONOIDES, page 84.

Figs. 1, 2, 3. Young individuals of this species.
" 4. An older individual.
" 5. A young specimen preserving two of the stipes, the funicle having been broken.
" 6. An enlargement from fig. 1, showing the radicle, funicle, and origin of the four stipes, with a few of the earlier cellules.
" 7. An older and larger specimen.
" 8. An enlargement from fig. 7 showing the character and proportions of the cellules.
" 9. A small individual, preserving the four stipes in part, which are somewhat more slender than the usual forms of this species.
" 10. An enlargement of the base of the specimen, showing the cell-denticles on one of the stipes, and a proportionally longer funicle than in fig. 8.
" 11. An extremely elongated stipe, the lower end showing the commencement of growth; the distal extremity is broken.

*** Figs. 9 and 10 may possibly prove to be distinct species. (See pl. iii, figs. 11, 12.)

GRAPTOLITHUS DENTICULATUS, page 88.

Fig. 12. A small imperfect specimen, preserving three of the stipes.
" 13. A larger and more nearly entire specimen, showing the four stipes. Their junction at the base is not quite satisfactorily shown.
" 14. A part of a single stipe, in which the cellules are well shown on one part; while they are compressed and nearly obliterated on the left of the curve.
" 15. An impression of a part of a stipe which is nearly straight; the imprint of the axis or thickened margin is not defined.
" 16. An enlargement from figure 14, showing the form of the cell-denticles, and the strong marginal axes; one portion represented with the substance remaining, and the other as an imprint.

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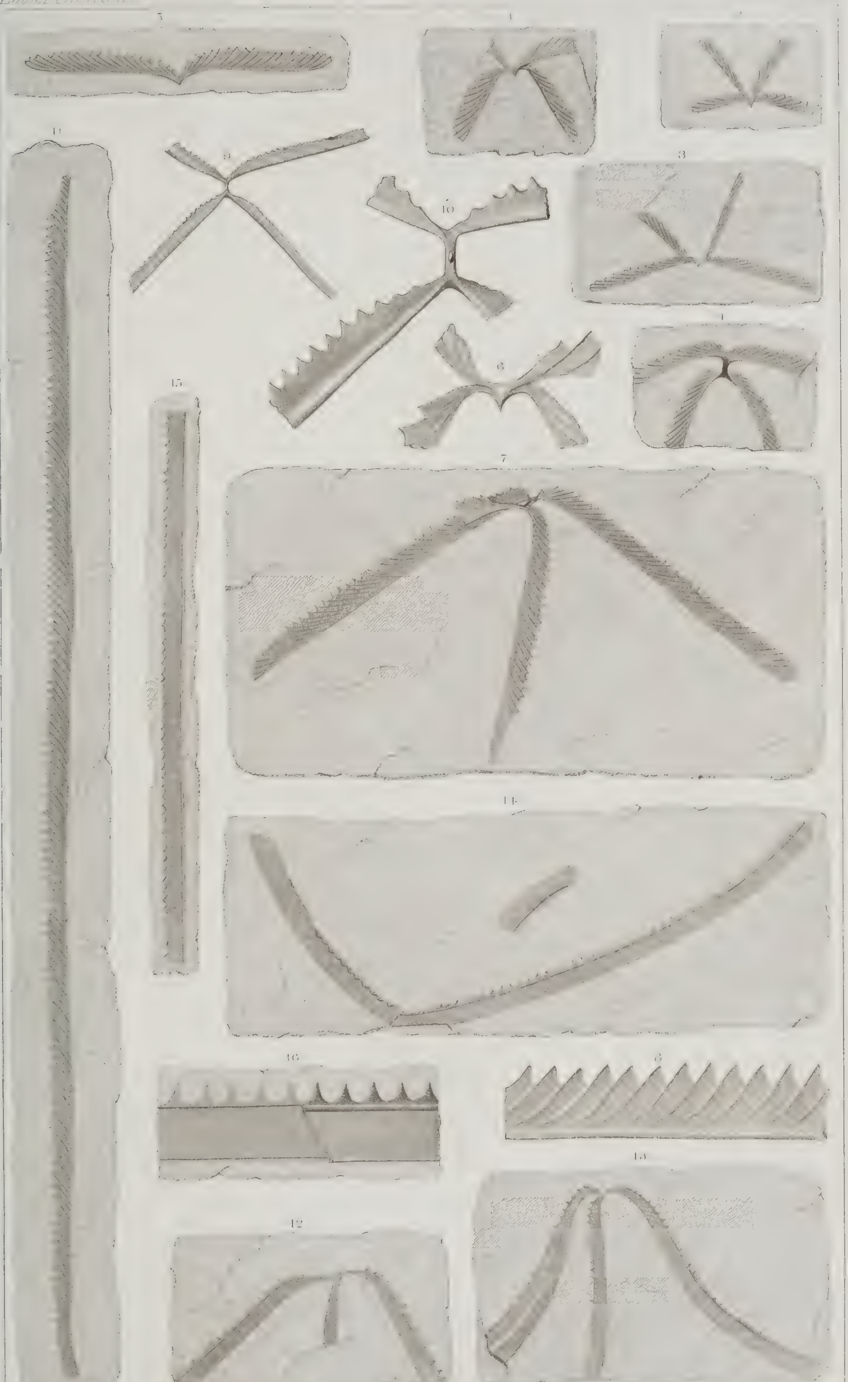
Decade 2

Lower Silurian.

Graptolitidae.

Plate 4.



R. P. Whitfield, Del.t James Hall, Descript.t James Duthie, Sc.

EXPLANATIONS OF PLATE V.

GRAPTOLITHUS QUADRIBRACHIATUS, page 91.

Fig. 1. A large specimen with stipes vertically compressed.
" 2. A young specimen in which one of the stipes appears to be subdivided.
" 3. An individual with stipes a little curved, the back of the stipe visible, and showing no serratures.
" 4. A frond with one of the stipes broken off; one showing the cellules and distinct striæ parallel to the cell-partitions, while the other two are turned so as to obscure the cellules.
" 5. An enlargement from fig. 1 : the stipe has been vertically compressed, causing the cellules to show a less angle with the stipe than in the normal condition.

GRAPTOLITHUS FRUTICOSUS, page 90.

Fig. 6. A small individual with the extremities of the radicle and stipes broken off.
" 7. An enlargement from fig. 6. The serratures are either imperfect or shrunken, and do not present the characters seen in better-preserved specimens.
" 8. An individual nearly entire, with an extremely long and slender radicle, but imperfectly preserved in the outline of its parts.

GRAPTOLITHUS PENNATULUS, page 82.

Fig. 9. A single stipe of this species? The specimen is a large stipe, somewhat obscurely preserved upon the surface of a slab of slate, with *G. extensus*, *G. bryonoides*, and *Phyllograptus ilicifolius*. It is from the same locality with *G. bifidus* at Point Lévis. In the form of the stipe, and its gradual diminution towards the distal extremity, as well as in the absence of visible pustules at the base of the cellules, it has the habit of *G. pennatulus*. Being the only individual observed from this locality, and the resemblance to *G. bifidus* being very close, I have referred it with much hesitation to *G. pennatulus*.

GRAPTOLITHUS CRUCIFER, page 92.

Fig. 10. View of the specimen from which the description is drawn.
" 13. The disc of a young individual probably of this species.

GRAPTOLITHUS HEADI (?) page 94.

Figs. 11 and 12. The central discs of two individuals which may belong to *G. Headi*.

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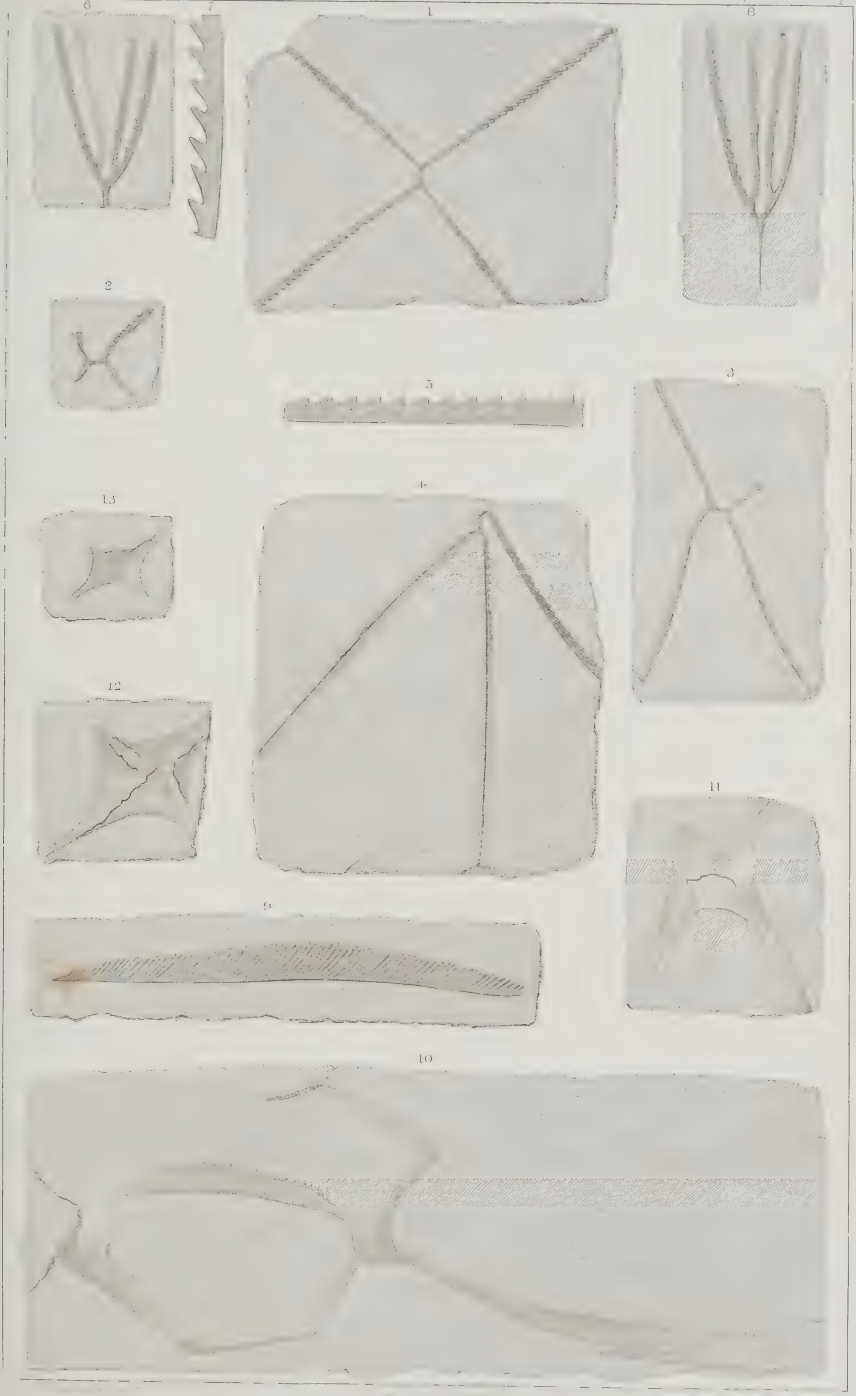
Graptolitidæ.

Lower Silurian. *Quebec Group.*



EXPLANATIONS OF PLATE VI.

GRAPTOLITHUS FRUTICOSUS, page 90.

Fig. 1. A fragment showing two of the stipes entire, and the bases of two others; the radicle extending to the margin of the specimen.

" 2. A specimen preserving three of the stipes, one of them entire, and showing some irregularities in the bifurcation where the one is broken off.

" 3. An enlargement of the right-hand stipe of the specimen fig. 1.

GRAPTOLITHUS BRYONOIDES, page 84.

Fig. 4. A frond in which three of the stipes, and the base of the fourth, are preserved. The specimen shows some peculiarity in the union of the parts by the slender funicle. From the river Ste. Anne.

GRAPTOLITHUS QUADRIBRACHIATUS, page 91.

Fig. 5. A frond preserving one stipe partially entire, and others broken off: the funicle and radicle-point are well preserved.

" 6. An enlargement from the specimen fig. 5, showing the form and proportions of cellules in their more perfect preservation, with the striæ parallel to the cell-margins well preserved.

GRAPTOLITHUS CRUCIFER? page 92.

Fig. 7. A central disc of *G. crucifer*, with the bases of the branches.

GRAPTOLITHUS HEADI, page 94.

Fig. 8. A representation of the specimen of the natural size, and as it occurs on the surface of the stone. (The upper separated portion of the stipe is placed a little lower in the figure than it is on the stone, in order to bring it within the dimensions of the plate.)

GRAPTOLITHUS ALATUS, page 93.

Fig. 9. The specimen represented as it occurs on a fragment of slate. The back of the stipes shows faint indentations, but they are made too strong in the engraving.

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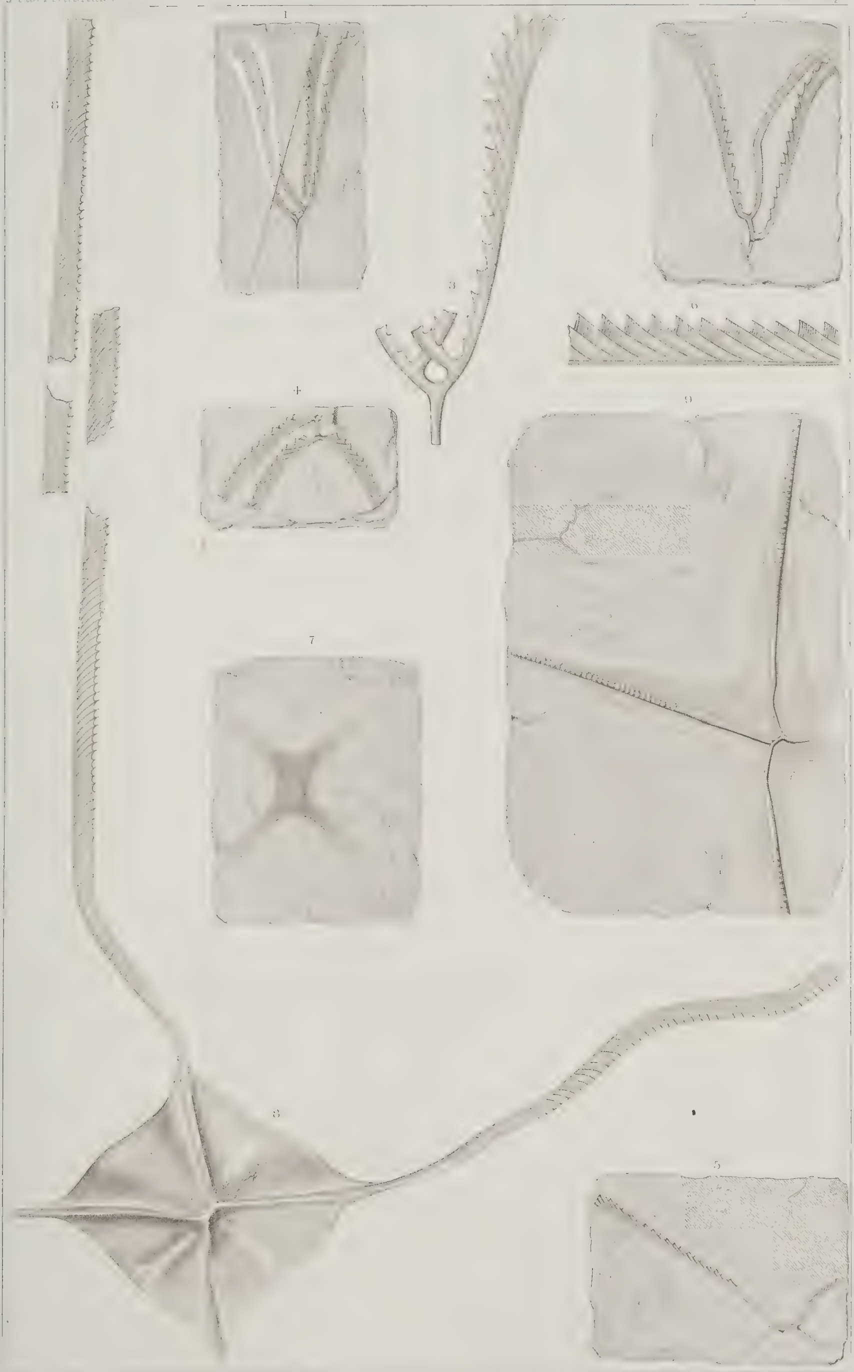
Decade 2. | Graptolitidæ. | *Plate 6.*

Lower Silurian. | *Quebec Group.*



R. P. Whitfield. Del.t James Hall. Descrp.t James Duthie. Sc.

EXPLANATIONS OF PLATE VII.

GRAPTOLITHUS OCTOBRACHIATUS, page 96.

Fig. 1. A large individual preserving two of the stipes to the length of eight inches, and another to nearly the same extent, while the rest are broken off at less distances from the disc. The flexibility of their substance is well shown in the recurved stipe at the left-hand side of the figures. Although this specimen preserves the most extended stipes of any in the collection, the disc is smaller than in several of the other specimens.

" 2. The exterior of a large disc of this species, with the stipes broken off a little beyond its margin. The two longer portions are so turned as to show the cellules.

" 3. A portion of a large disc, showing the exterior or non-celluliferous face of the frond, and preserving portions of four of the stipes.

" 4. A frond with the stipes broken off at different distances from the centre. The substance of the disc or cup is imperfect,—a condition which apparently existed while the body was in a living state.

" 5. An enlargement from one of the stipes of fig. 1, at *c*, looking upon the apertures of the cellules, which are somewhat compressed.

" 6. An enlargement from the same at *b*, where the substance is laterally compressed.

" 7. An enlargement from the same, where the substance is obliquely compressed at *a*.

Figs. 5 and 7 are taken from casts made in the impressions left by removal of the substance of the graptolite.

EXPLANATIONS OF PLATE VIII.

GRAPTOLITHUS OCTOBRACHIATUS, page 96.

Fig. 1. A symmetrical frond preserving parts of all the stipes, two of them apparently almost entire ; several of them had been abruptly bent before being imbedded in the stone.

2. A frond preserving eight stipes, but without a disc. The specimen does not afford any evidence that a disc has ever existed.

" 3. A frond with small disc and somewhat slender stipes. One side preserves the usual character of four stipes, while the other has but three.

" 4. A frond which is abnormally developed ; one side exhibiting the four stipes with the disc, while on the other side the funicle is apparently extended in a single stipe only.

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Decade 2.

Lower Silurian.

Graptolitidæ.

R. P. Whitfield Delᵗ. James Hall, Descrptᵗ. James Duthie, Sc.

EXPLANATIONS OF PLATE IX.

GRAPTOLITHUS LOGANI, page 100.

Fig. 1. A specimen of slate, preserving portions of three individuals (two only given in the illustration). The disc had probably been removed by maceration before they were imbedded, but the stipes are preserved to a length of more than seven inches. It does not appear that this exhibits the entire skeleton : the stipes were originally longer. The serrated margins are not always shown at equal distances from the centre ; but this is due to accidental position, some stipes showing the exterior surface for some distance, and then gradually turning and becoming flattened laterally.

" 2. A specimen showing the disc almost entire.

" 3. An individual showing the exterior surface the central portions entire, with the impression of the connecting disc, some portions of which remain attached to the stipes. The extent and outline of the disc are distinctly seen. The appearance of serratures is due to exfoliation, which shows the impression of the celluliferous side of the stipe upon the stone.

" 4. A specimen exhibiting the half of an individual, with the disc unequally extended between the rays. The margins are all apparently entire, and this inequality, to whatever accident due, existed in the living animal.

" 5. Exterior view of an individual showing some remaining portions of the disc ; the stipes are all broken off beyond the bifurcations.

" 6. Another individual showing the inner side, with the commencement of the cells, which appear in some places in double series. The substance of the disc is removed.

" 7. Enlargement of the exterior surface of the central portion of the specimen fig. 5.

" 8. Enlargement of the inner surface of the specimen fig. 6, giving the appearance of a double series of cells separated by a depressed line in the substance of the stipe. Sometimes this separation appears to be actual, while elsewhere the apparent division is due to the depression along the centre.

" 9. Enlargement of a fragment of a stipe, showing the form and proportions of the cellules.

EXPLANATIONS OF PLATE X.

Graptolithus octonarius, page 95.

Fig. 1. A specimen of natural size, much broken and distorted from pressure.
" 2. An enlargement from the preceding figure.

Graptolithus flexilis, page 103.

Fig. 3. A fragment of slate preserving more than half of a frond, and showing the folding and crossing of some of the branches.
" 4. A fragment preserving parts of three individuals, the extremities of the branches all broken off.
" 5. The central portion of the frond of another individual.
" 6. Separated branches preserving the cellules in unusual perfection.
" 7. An enlargement of the centre of the frond, fig. 5, showing the short radicle and the usual mode of branching. The central part of the axis is rounded, with a narrow corneous alation at the sides.
" 8. A bifurcated fragment enlarged, from fig. 4: the cellules have been flattened vertically, causing them to be visible in slight indentations on both sides of the axis.
9. A portion of a branchlet enlarged from fig. 6, showing one part compressed laterally, with the cellules fully expanded, while the other, on the right hand, is gradually twisted so as to show only the back of the branchlet.

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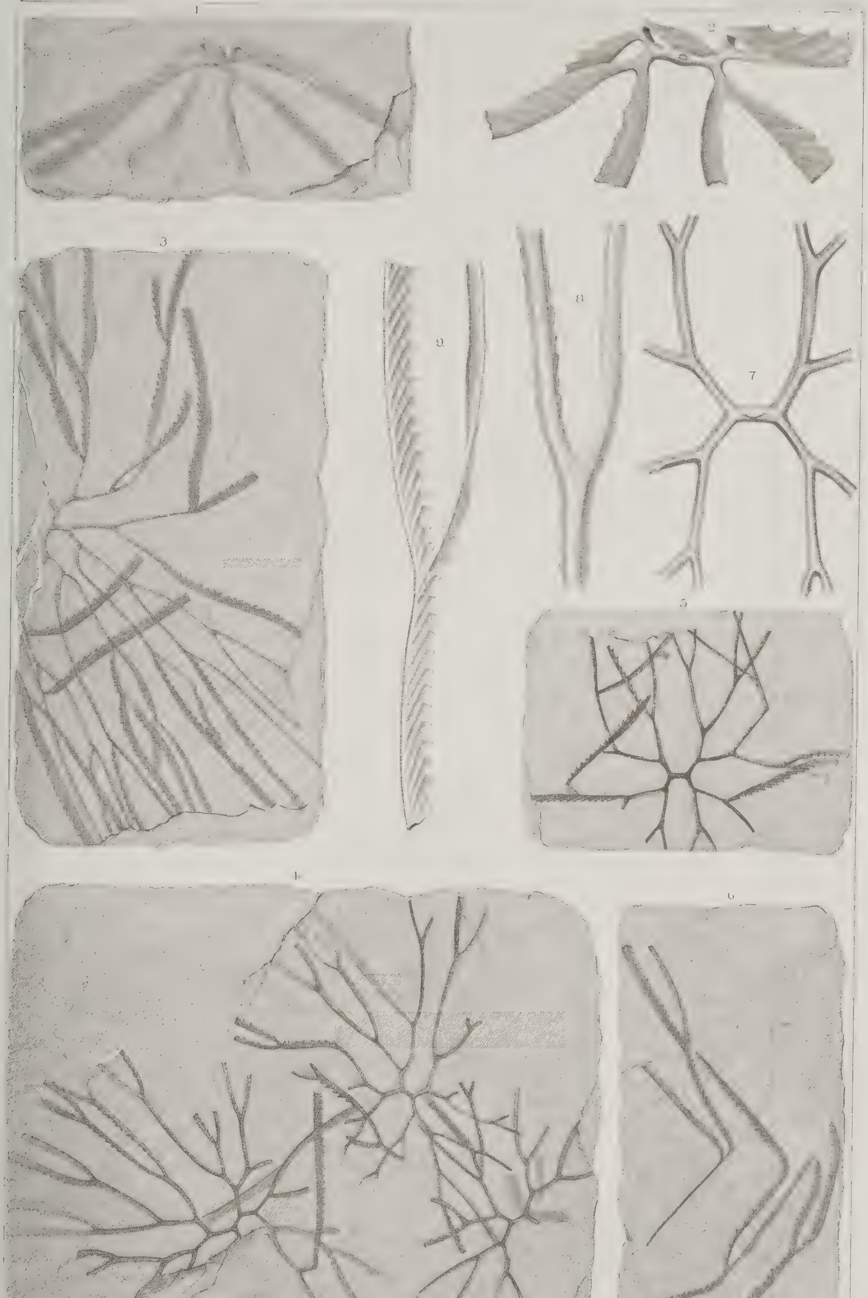
Graptolitidæ.



James Hall, Descrpt.

EXPLANATIONS OF PLATE XI.

GRAPTOLITHUS RIGIDUS, page 105.

Fig. 1. A fragment preserving the centre and principal branches.
" 2. A larger specimen, showing the principal ramifications of the branches. This and the preceding specimen show only what appears to be the non-celluliferous portion of the frond.
" 3. The extreme parts of some branchlets laterally compressed, showing the celluliferous parts of the frond.
" 4. An enlargement of one of the branchlets of fig. 3.
" 5. A strong branch with part of the branchlets, showing the lower side or non-celluliferous portion of the frond.

GRAPTOLITHUS ABNORMIS, page 106.

Fig. 6. A fragment of slate preserving the centre and the branches on one side to beyond the first bifurcation. The other side is imperfect, and apparently less developed.

GRAPTOLITHUS LOGANI, page 100.

Fig. 7. The central part of an individual without disc, showing five stipes on one side and four on the other. This is supposed to be an abnormal form of *G. Logani.*

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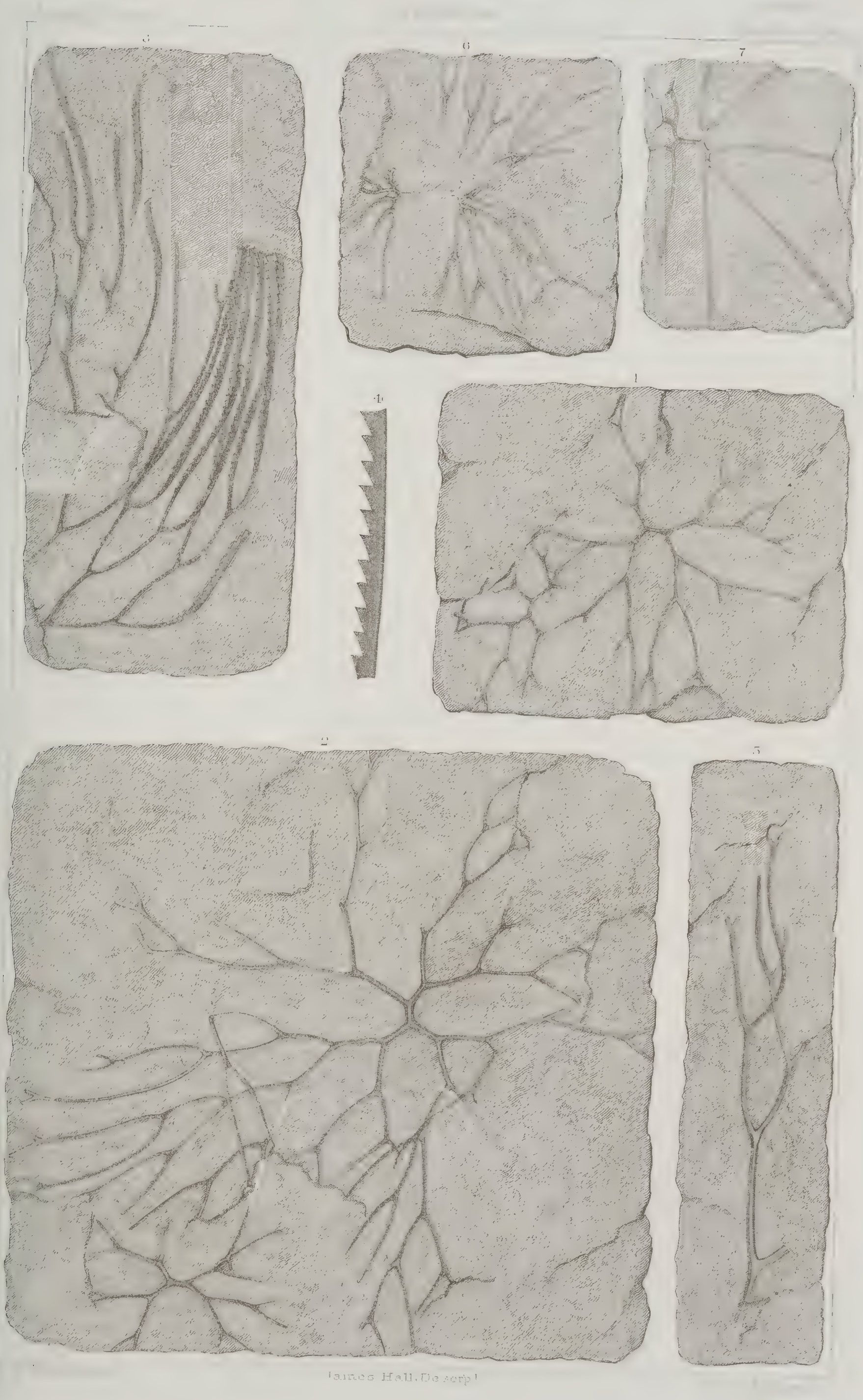
Sir W



James Hall, Del. sculp.

EXPLANATIONS OF PLATE XII.

GRAPTOLITHUS RICHARDSONI, page 107.

Fig. 1. A fragment of slate, preserving a stipe, with six branches in its apparent continuation, and impressions of two others in the intermediate space; two of these again bifurcating.

" 2. A fragment preserving several branchlets, which are compressed in different directions, showing the sides and apertures of the cellules.

" 3. An impression of a bifurcating fragment, the cellules of which were filled with mineral matter and vertically compressed.

" 4. A fragment of a branch laterally compressed.

" 5. The impression of a bifurcating branch where the cellules are somewhat obliquely compressed, and partially filled with mineral matter.

" 6. A fragment enlarged, giving a lateral view of the cellules.

" 7. An enlargement from an impression of a branchlet, from fig. 5, which is obliquely compressed, having the cellules filled with mineral matter.

" 8. Enlargement of a fragment, from fig. 1, where the cellules are filled with mineral matter and vertically compressed.

GRAPTOLITHUS RAMULUS, page 108.

Fig. 9. A small bifurcating branch.

" 10. An enlargement of fig. 9, showing the form and extent of the cellules.

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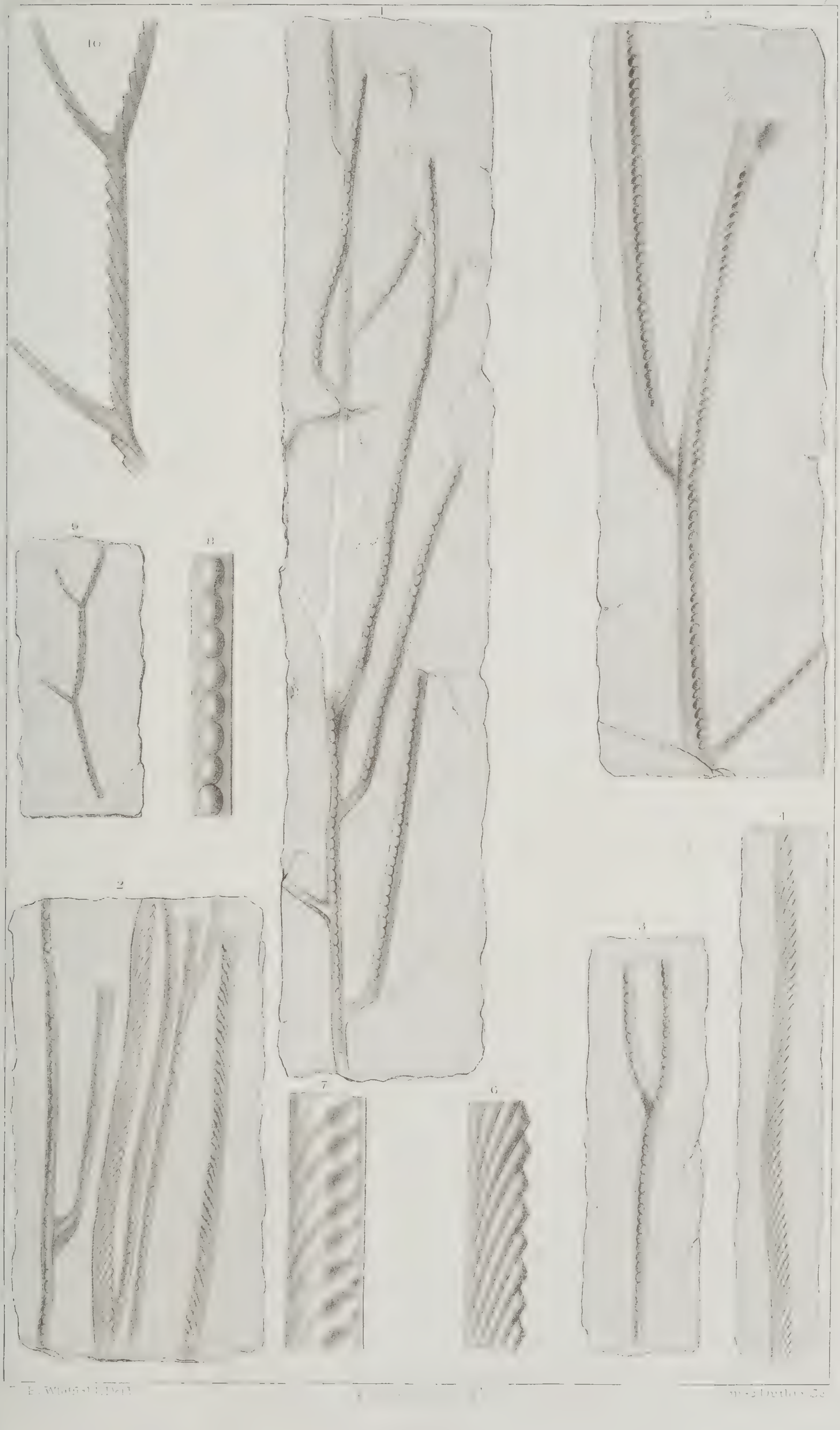
Graptolitidæ

Plate 12

uebec Group



EXPLANATIONS OF PLATE XIII.

GRAPTOLITHUS QUADRIMUCRONATUS, page 144.

Fig. 1. Part of a stipe compressed in a slightly oblique direction, still showing the cellules on the two sides.
" 2. A stipe compressed more obliquely, so as nearly to obscure the cellules on one side.
" 3. A specimen compressed vertically to the celluliferous side of the stipe.
" 4, 5, and 6. Enlargements from specimens, figs. 1, 2, and 3 respectively.
" 7. Enlargement from a specimen where the solid axis lies near to one side.
" 8. A specimen obliquely compressed, so that the mucronate points at one angle of the cellules of the left side, are pressed through the test, and show on the surface as a range of pustules. The axis is displaced, and seen on one side of the centre.
" 9. A diagram representing a theoretical longitudinal section.
" 10. A transverse section of a stipe with the mucronate extensions of the cell-margins.

CLIMACOGRAPTUS ANTENNARIUS, page 112.

Fig. 11. A young individual, compressed in such a manner that the cell-apertures are not shown upon the margin.
" 12. A flattened stipe, presenting only the mucronate terminations of the cell-apertures beyond the margin.
" 13. An older individual, showing the margins of the stipe extending beyond the cell-apertures, while the cellules are visible in the substance of the stipes as darker areas.

DIPLOGRAPTUS INUTILIS, page 111.

Fig. 14. A piece of slate preserving fragments of two individuals.

DIPLOGRAPTUS PRISTINIFORMIS, page 110.

Fig. 15. A fragment of a stipe, showing the usual form and proportions of the best-preserved specimens.
" 16. A smaller individual, with the mid-rib or axis extending beyond the body of the stipe.
" 17. An enlargement from fig. 16, showing more distinctly the form of the cellules.

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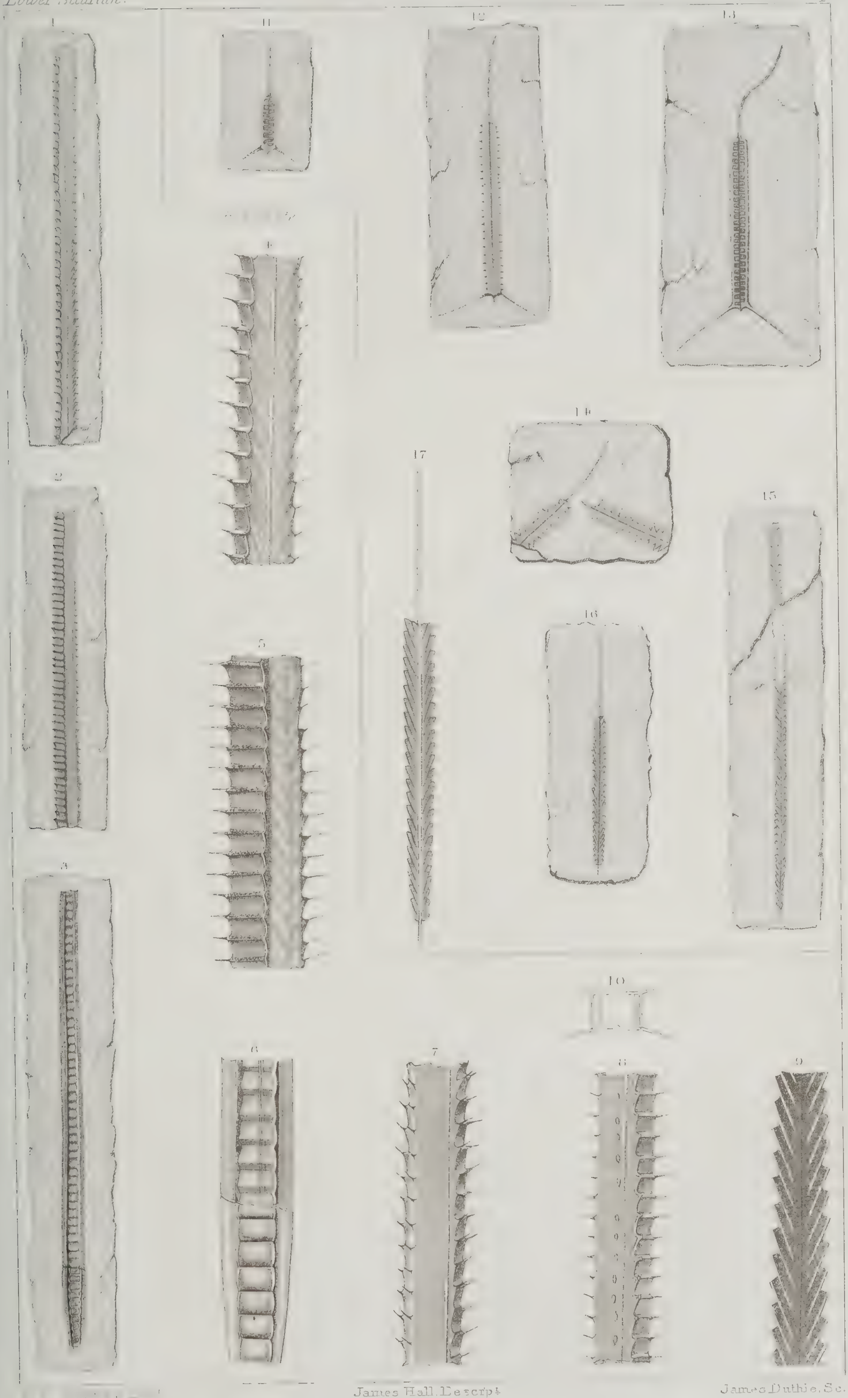
Decade 2. *Plate 13.*

Lower Silurian. *Quebec Group.*



James Hall Descript. James Duthie. Sc.

EXPLANATIONS OF PLATE XIV.

RETIOLITES ENSIFORMIS, page 114.

Figs. 1, 2, 3. Individuals showing gradations in growth, and slight differences in their proportions.
" 4. A nearly entire stipe of the largest size observed.
" 5. An enlargement from the specimen fig. 2.

RETIOGRAPTUS TENTACULATUS, page 116.

Fig. 6. An individual of the natural size, with the marginal reticulations nearly entire.
" 7. The preceding specimen enlarged.
" 8. An enlargement of another individual, where the marginal reticulations are but partially preserved.

RETIOGRAPTUS EUCHARIS, page 146.

Fig. 9. An illustration of a compound form of the genus, enlarged to four diameters.

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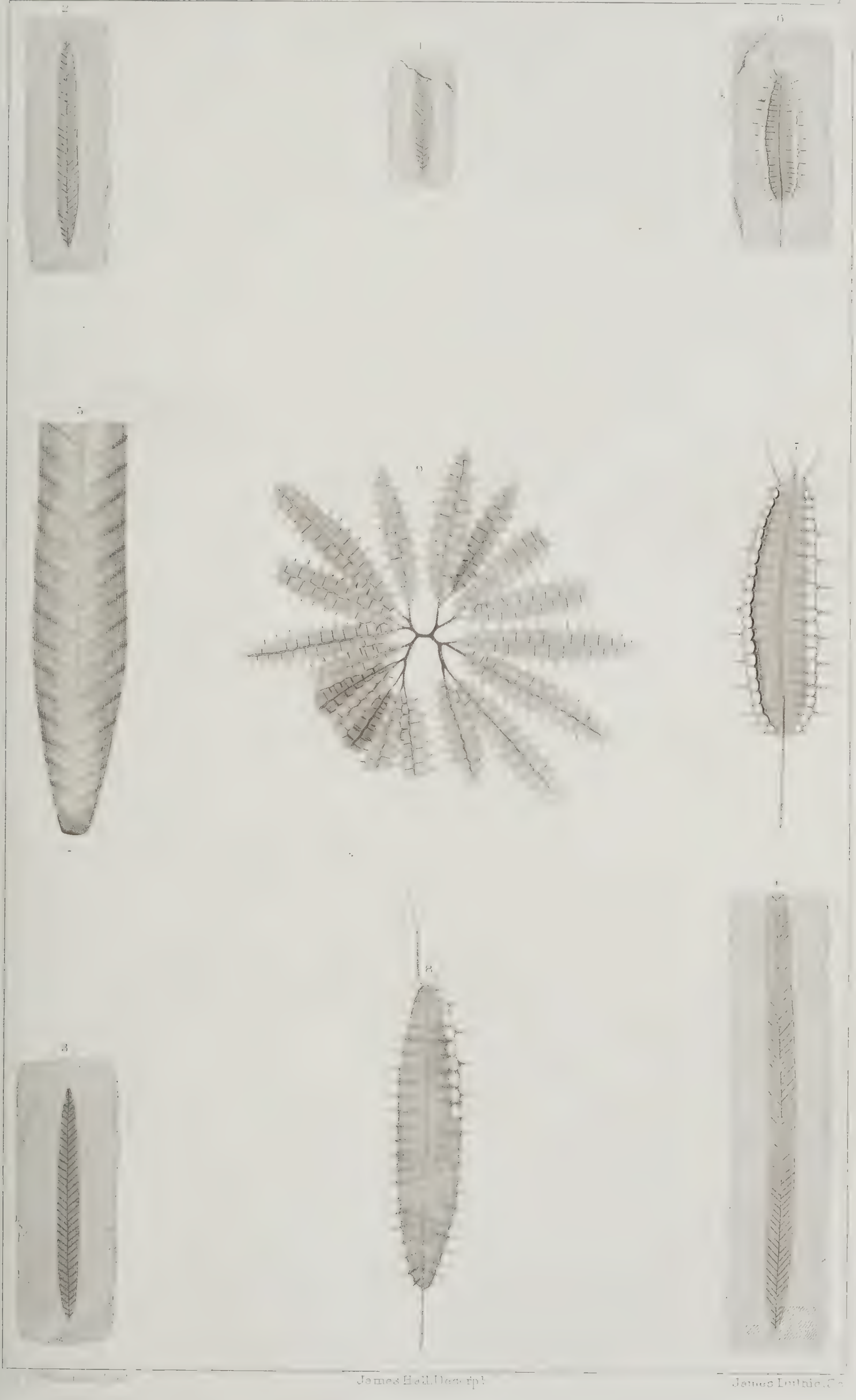
Decade 2.

Lower Silurian.

Graptolitidæ.

Plate 14

Quebec Group



James Hall, Del. et pt.

James Duthie, Sc.

EXPLANATIONS OF PLATE XV.

PHYLLOGRAPTUS TYPUS, page 119.

Fig. 1. An extremely short and broad form of this species, with the axis broad, and showing some remains of the cellules at the base of the separated division.

" 2. An elongate-ovate form of stipe, with a broad axis, which does not show remains of cellules. Some of the cellules in the upper part of the stipe are filled with iron pyrites.

" 3. A form similar to the preceding, showing remains of cellules on the upper part of the axis.

" 4. An elliptical form of stipe, where two of the divisions have been separated leaving the bases of two sets of cellules.

" 5. A broadly elliptical form, from which two of the divisions and the axis have been removed; showing the bases of the cellules of the folia which remain in the slate.

" 6. A stipe compressed in the same direction as fig. 3 of the generic illustrations page 119; with a part of one of the folia removed, but not reaching to the axis. The lines of the cell-partitions appear as if continued across the axis.

" 7. An elongate-lanceolate form of stipe, which does not show cellules in the line of the axis.

" 8. An elongate-elliptical and very symmetrical specimen, showing the marks of cellules along the axis, which is unusually narrow.

" 9. A part of a stipe folded in the manner of fig. 6, the upper portion of one side preserving only the impression of the substance. In the lower part, the cell-markings on the axis should be shown more distinctly.

" 10. A group of small stipes upon the surface of a piece of shale. These are given in their natural size and in their actual relations to each other.

" 11. An enlargement of a part of an impression of a stipe which has been flattened in the direction of figs. 6 and 9. A portion of the substance remains, as shown on the left hand; the cellules filled with iron pyrites.

" 12. An enlarged portion from a stipe, showing the double cell-denticles and corresponding cell-partitions. The narrow spaces on the surface of the figure are more elevated than the wider ones, with a greater thickness of the substance; which I suppose may have been caused by the cell-partitions, which are obliquely compressed, thus showing the cell-denticles. These elevated spaces become gradually narrower towards the axis, in accordance with the form of the cells, as shown in the theoretical figure 10 plate xvi.

Geological Survey of Canada.

Quebec Group.

EXPLANATIONS OF PLATE XVI.

PHYLLOGRAPTUS ILICIFOLIUS, page 121.

Fig. 1. An individual of the natural size, where the folia *b*, *a** are broken entirely away beyond the axis, leaving the bases of the cellules of two adjacent folia visible, except at the upper part of the figure, where two or three of the bases of the other cellules remain.

" 2. A similar specimen, showing the bases of a set of cellules on each side of the centre, with two or three of those belonging to the broken folium at the base of the figure.

" 3. An enlargement of fig. 2, showing more distinctly the cellules on each side of the central line, and the small remaining portion at the base.

" 4. A specimen of the natural size, where one folium is broken away not quite so far as the axis, leaving the bases of its cellules visible.

" 5. An enlarged figure from a specimen which has been imbedded transversely. Three of the divisions have been broken away, leaving impressions of the lateral ones only, and of the cell-bases and cell-partitions of the fourth division, which are directed obliquely upwards from the axis and point of view. The lower part of the specimen preserves a portion of the lateral folia, with the bases of the cells of the outer division *a**, which are directed towards the axis.

" 6. An enlargement of a specimen which is imbedded obliquely, or in a direction as if the theoretical figure 10 were vertically compressed, leaving no visible axis. In the lower half of the specimen, the fossil has been separated in the opposite slaty laminæ, leaving only the impression of that side, which also shows no axis. In the upper half of the specimen, the cellules are well preserved, and on the left-hand side the apertures are conspicuous. Enlarged to three diameters.

It will be observed that the impression is not quite in the same direction as the outline in the upper portion of the figure, owing to the obliquely-compressed folia.

" 7. A specimen compressed in the same manner as fig. 6; the upper folia have however been separated, except the bases of a few of the cellules in the upper part of the figure, leaving the other two folia imbedded in the shale, and showing the bases of their cellules ascending from the axis. Enlarged to three diameters, as in fig. 6.

" 8. An enlarged figure of a specimen compressed in the direction first described without any separation of the parts; from which cause there is no proper axis visible. In this condition, the specimens resemble *Graptolithus folium* of Hisinger, or *G. ovatus* of Barrande.

" 9. An enlargement of a specimen compressed as in fig. 8, but with the cellules filled, and the margins of the upper two folia broken, showing the cell-openings. (8 and 9 are enlarged to twice their natural size.)

" 10. A restoration of the form of *P. ilicifolius*, showing the four divisions; which are represented as cut through transversely, exhibiting the cell-cavities.

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* These letters refer to the illustrative figures, page 119.

EXPLANATIONS OF PLATE XVI, continued.

PHYLLOGRAPTUS ANNA, page 124.

Fig. 11. A specimen with the folia obliquely compressed.

" 12, 13, 14. Individuals showing some varieties of form. The specimens have all been so imbedded that one of the folia has been torn away in the separated laminæ of shale, leaving an axis marked by the bases of its cellules.

" 15. An enlargement of a specimen which has one of the laminæ vertically imbedded, and shows the bases of the cells as they recede from the axis. The markings at the sides are from the impressions of the folia, except a small fragment of one remaining on the left-hand side of the figure.

" 16. An enlargement from a specimen where the two lateral folia remain, showing the bases of the cells of the folium which has been broken off, in the separated laminæ of slate. The surface is distinctly striated.

PHYLLOGRAPTUS ANGUSTIFOLIUS, page 125.

Fig. 17. A small and comparatively wide specimen, with a distinct linear axis, but without evidence of cellules.

" 18. A more elongate specimen, with distinct axis, with a darker line in the centre.

" 19, 20, 21. Varieties of form and proportion. The specimen fig. 21 is the largest observed.

This species is placed under *Phyllograptus* from its similarity in form to others of the genus, although evidence of the quadruple division has not been established. The want of parallelism of the margins, and the subelliptical form would, I conceive, be sufficient to remove it from the genus *Diplograptus*.

GRAPTOLITHUS BIGSBYI, page 86.

Figs. 22, 23, and 24 illustrate a common condition of this species, where two of the divisions show the lateral faces, while the non-celluliferous edge of a third division is seen lying nearly vertically in relation to these. The fourth division has been broken off in the separated film of slate.

" 25. A specimen showing the lateral faces of two divisions. Below these, in the shale, are seen the non-celluliferous edges of the two other divisions.

" 29 and 30 show a still closer arrangement of the parts, and the contiguity of the non-celluliferous edges at the apices, which are scarcely perceptibly separated in the shale.

" 26. An individual where the apices of the divisions are in contact, either conjoined, or accidentally so placed, with a narrow space in the centre. In obscure specimens it is difficult to separate such forms from *Phyllograptus*.

" 27. An individual where the divisions are equally spreading: one of them preserving only the base of the stipe.

" 28. The same enlarged.

Geological Survey of Canada.

ames Hall, D. sculpt

James Duthie, Sc.

EXPLANATIONS OF PLATE XVII.

Dendrograptus flexuosus, page 127.

Fig. 1. A small frond of the natural size.
2. A part of a larger frond.

Dendrograptus divergens, page 129.

Figs. 3, 4. A specimen of natural size, and an enlargement of the same.

Dendrograptus striatus, page 129.

Fig. 5. A fragment of a frond, preserving the bases of some of the branches.
" 6. A portion of the non-celluliferous surface enlarged.

Dendrograptus erectus, page 130.

Fig. 7. The principal stipe, and bases of some of the branches, of the natural size.

Dendrograptus fruticosus, page 131.

Fig. 8. A frond which is apparently nearly entire.
" 9. A more diffuse form of the same species, with some of the branches broken off.

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Graptolithidae.

EXPLANATIONS OF PLATE XVIII.

Dendrograptus? (Callograptus?) diffusus, page 132.

Fig. 1. A portion of a broken frond from near the base. The test is removed in some parts, showing celluliferous markings.
" 2. A fragment of another specimen with similar cell-markings.
" 3. An enlargement, showing the cell-apertures. The specimens are extremely compressed.

Callograptus elegans, page 134.

Fig. 4. A fragment which is more lax and spreading, with shorter branchlets than the ordinary specimens, but having similar striæ, and a similar arrangement of cellules.

Dendrograptus gracilis, page 132.

Fig. 5. Two of the larger branches with their sub-divisions, of the natural size.
" 6. An enlargement from one of the branchlets, showing the striate surface and the deep indentation of the cellules.

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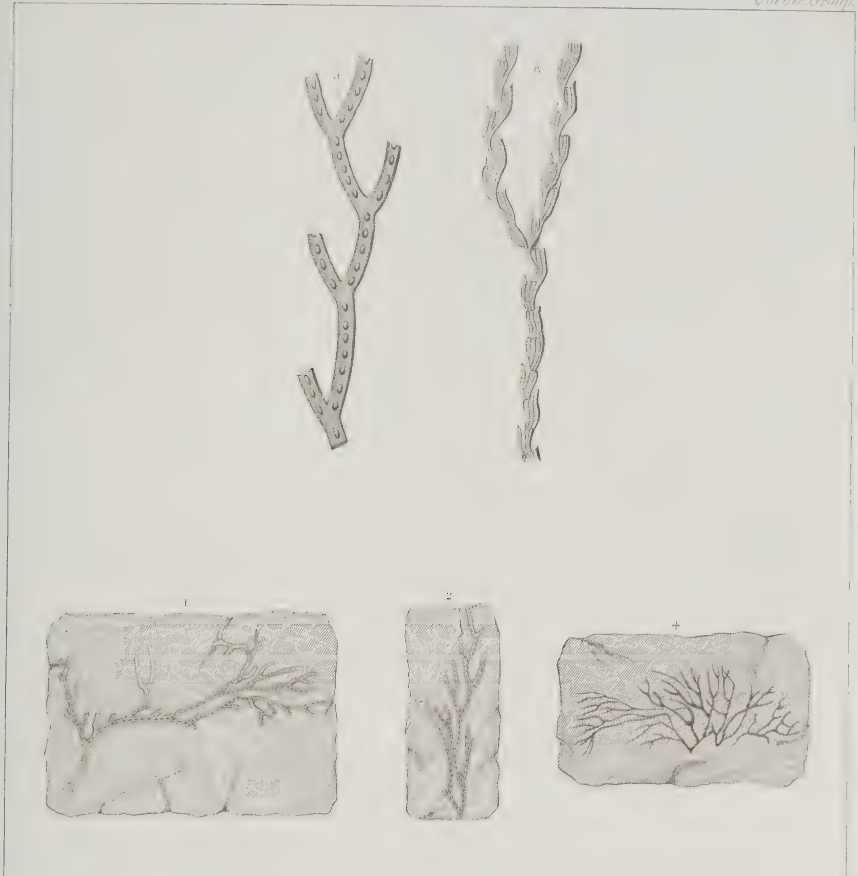
Decade 2. | Graptolitidæ. | Plate 18.

Lower Silurian. | | Quebec Group.



R. P. Whitfield, Del.t James Hall, Descript

EXPLANATIONS OF PLATE XIX.

Callograptus elegans, page 134.

Fig. 1. A fragment of a frond, natural size.

" 2. A nearly entire flabelliform frond. The two shaded lines running nearly vertically through the figure, are due to faults or slips in the slate, causing a slight overlapping of the laminæ, and an interruption of the continuity of the frond.

" 3. An enlargement, showing the lateral connection of the branches at irregular intervals.

" 4. A further enlargement of the non-celluliferous side of a bifurcating branchlet, showing the striated surface and a semi-articulate structure.

Callograptus Salteri, page 135.

Figs. 5, 6. Fragments of two distinct fronds; one showing the celluliferous side, and the other the non-celluliferous side.

" 7. An enlargement from the non-celluliferous side, showing a few transverse dissepiments at irregular intervals. The figure has the same degree of enlargement as fig. 3 of *C. elegans*.

" 8. A farther enlargement of a bifurcating branchlet, showing the cell-apertures.

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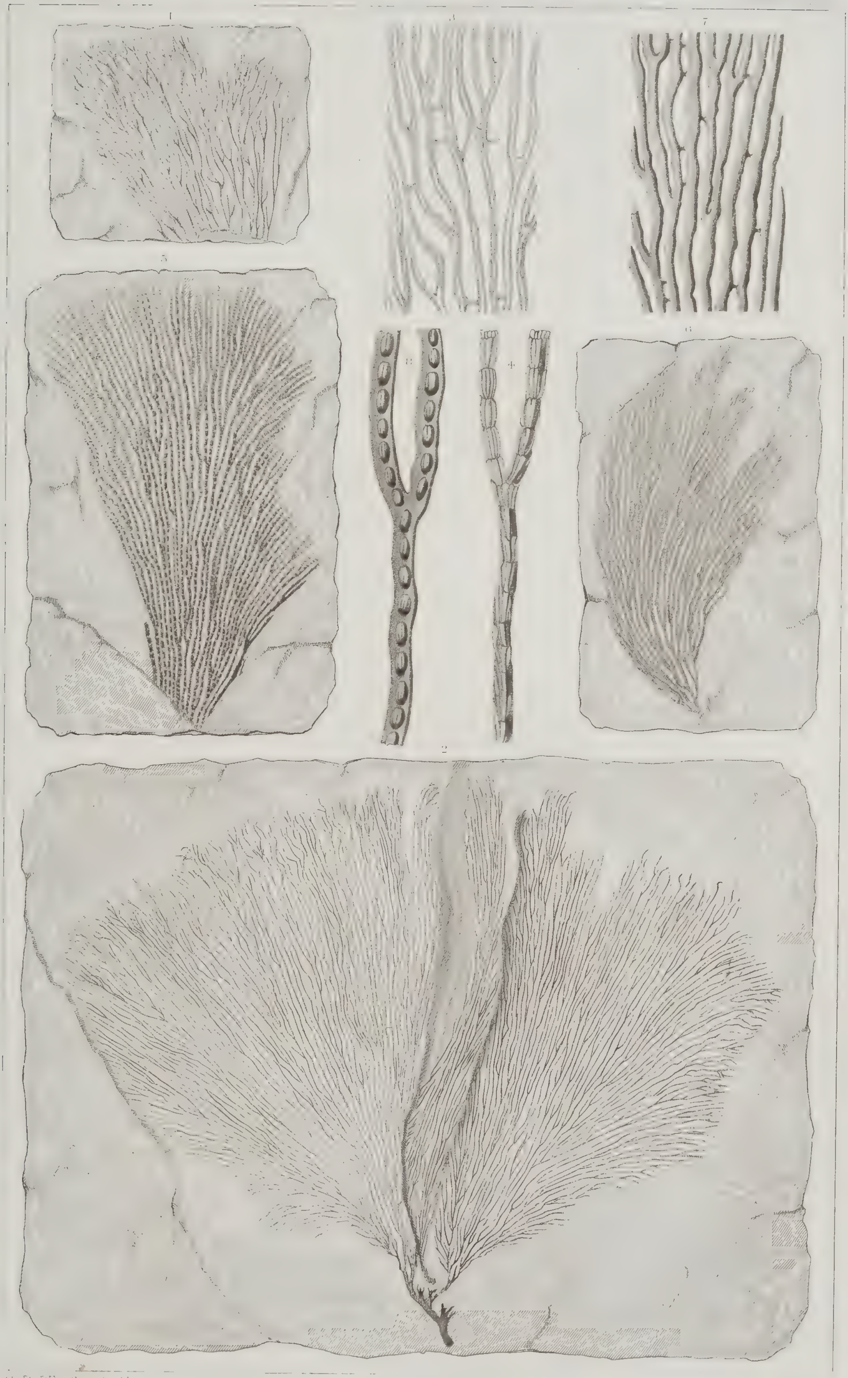

R. P. Whitfield, Del.t Jan

EXPLANATIONS OF PLATE XX.

DICTYONEMA IRREGULARIS, page 136.

Fig. 1. A fragment from near the base of a frond.
" 2. A fragment from the outer portion of the frond.

DICTYONEMA ROBUSTA, page 137.

Figs. 3, 4. Fragments of two different fronds. In some parts of the specimen fig. 3, and in all of fig. 4, the branches are extremely flattened and attenuate.

DICTYONEMA QUADRANGULARIS, page 138.

Fig. 5. A fragment of a frond, of the natural size.

DICTYONEMA MURRAYI, page 138.

Figs. 6, 7. Fragments of two fronds ; the figures of the natural size.

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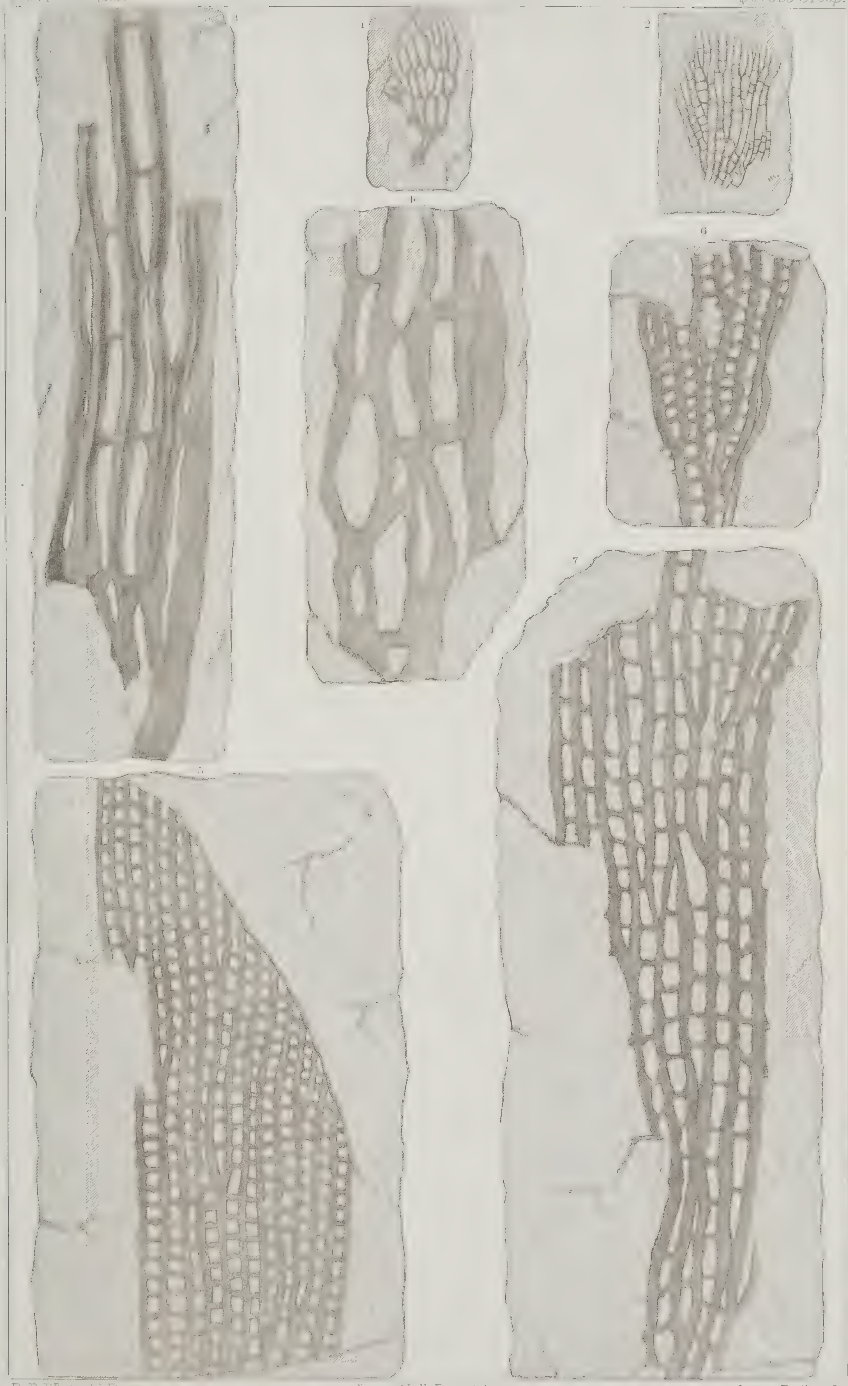
Decade 2

Graptolitidae

Quebec Group.



R. P. Whitfield, D.

James Hall, Descrip.

James Duthie, Sc.

EXPLANATIONS OF PLATE XXI.

PTILOGRAPTUS PLUMOSUS, page 140.

Fig. 1. A fragment which is three times branched.
" 2. A slender simple branch.
" 3. An enlargement from the specimen fig. 1.
" 4. A further enlargement of a portion of the same; some of the branches showing markings like cell-apertures.

PTILOGRAPTUS GEINITZIANUS, page 140.

Fig. 5. A branching fragment showing the celluliferous side.
" 6. A fragment which is irregularly branched, showing the non-celluliferous side.
" 7. A single branchlet of the same species.
" 8. An enlargement from fig. 5, showing the cell-apertures.

THAMNOGRAPTUS ANNA, page 141.

Fig. 9. A fragment of the species, of the natural size.

Geological Survey of Canada.

Decade 2. Plate 22

Lower Silurian. Graptolitidæ? Quebec Group.

R. P. Whitfield, Del^t. James Hall, Descrp^t. James Duthie, Sc.

GEOLOGICAL SURVEY OF CANADA.

SIR W. E. LOGAN, F.R.S., DIRECTOR.

FIGURES AND DESCRIPTIONS

OF

CANADIAN ORGANIC REMAINS.

DECADE III.

Montreal:
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1858.

CONTENTS.

PREFACE.

One of the subjects comprehended in the recommendation of the Select Committee appointed by the House of Assembly, on the Geological Survey, in 1854, was the publication of figures and descriptions illustrative of such new organic forms as might be obtained in the progress of the investigation. In compliance with this recommendation, it was determined that the publication should be made in parts or decades, after the mode adopted by the Geological Survey of the United Kingdom, each part to consist of about ten plates, with appropriate descriptive text, and to comprehend one or more genera or groups of allied fossils, or the description of several species, for the illustration of some special point in geology.

The first part or decade was confided for description, in 1855, to Mr. J. W. Salter, one of the Palæontologists of the Geological Survey of the United Kingdom. This comprehends different genera and species from one locality. Of these several are new, while others are more perfect forms of species already partially described; and the general object is to exhibit a commingling of forms heretofore supposed to belong to distinct epochs. The plates of this decade are the work of Mr. W. Sowerby, from drawings by Mr. R. C. Bone. The engravings are on steel; nine of the plates are finished, and it is expected the tenth will be completed in a short time.

The second decade was undertaken also in 1855, by Mr. James Hall of Albany, so justly celebrated for his works on the Palæontology of New York. It will comprehend the description of a large number of remarkable new forms of *Graptolithus* and allied genera from the Hudson River group. The drawings are by

Mr. F. B. Meek. Six plates have been engraved on steel by Mr. J. E. Gavit, and ten more plates are in the engraver's hands. The number of species will probably be twenty-four, of which Mr. Hall has already given a description in the Report of Progress for the year 1857.

On the appointment of Mr. E. Billings as Palæontologist of the Survey, in 1856, his first duty was to effect an arrangement of the Museum. This being accomplished, he devoted his attention to a third decade. This comprehends all the Cystideæ and Star-fishes, as well as all the Entomostraca, of the collection. With the view of obtaining the plates necessary for the illustration of these, Mr. Billings, in the month of February last, carried his fossils to London. Finding that considerable delay was likely to attend the publication of the decade should he illustrate it by engravings on steel, he determined to have recourse to lithography. Although minute detail cannot be so finely given by this mode, nor so large an edition be obtained, it is yet perfectly suitable for all practical purposes. It is occasionally used for the fossils of the British Survey, and very generally for the illustration of the best palæontological works on the continent of Europe. The twelve plates which illustrate the third decade are the work of several well-known artists, who have all their respective merits. One of the plates is by Mr. R. C. Bone, two of them by Mr. J. Dinkle, four by Mr. Tuffen West, three by Mr. H. S. Smith, one by Mr. W. Sowerby, and one by Mr. G. West. Of the descriptive part, the Cystideæ and Star-fishes are by Mr. E. Billings; the genus Cyclocystoides by Mr. Salter and Mr. Billings; and the Entomostraca by Mr. T. R. Jones, assistant-secretary of the Geological Society of London, who is considered the best authority on this particular family of animals, and had previously described a large number of the Canadian species.

While Mr. Billings was attending to the progress of his decade in London, it appeared doubtful which of the three that were in hand would be first ready for publication. He, in consequence, caused to be registered on the plates, as the number of the decade, the figure which indicates the order in which it was commenced.

It therefore appears as the third decade, but being the first ready, and the subject quite distinct from those of the other two, no hesitation is experienced in placing it first before the public.

Mr. H. S. Smith, who, as already stated, supplied three of the plates, has been induced to come out to Canada with the design of devoting his attention to the representation of the fossils of the Provincial collection; and it will therefore in future be unnecessary to go out of the country for the illustration of them, unless it be to procure the aid of the best authority on some special subject.

Of the third decade an edition of 2000 copies is issued. Of these 500 copies are reserved for the members of the Legislature; and it is intended to fix upon the remainder a moderate price, and dispose of them to the public through some respectable bookseller. By this means it is hoped that they will fall into the hands of those who will really appreciate them. The same course will be pursued in respect to the first and second decades, when they are ready.

A fourth decade is now in hand which will illustrate the Crinoids of the collection.

W. E. LOGAN.

Montreal, 30th June, 1858.

CANADIAN ORGANIC REMAINS.

On the CYSTIDEÆ *of the Lower Silurian Rocks of Canada.* By E. BILLINGS, F.G.S.

SECTION I.

GEOLOGICAL POSITION, STRUCTURE AND CLASSIFICATION.

I. *Introductory Observations.*

As several elaborate and beautifully illustrated memoirs upon the structure and affinities of the Cystideæ have appeared during the last few years, it would be superfluous, on the present occasion, to enter upon a re-examination of the subject, were this decade designed to circulate only among scientific men, for whom it would be sufficient to give nothing more than the most concise technical descriptions of the species. But being intended also for the use of the students of Canadian geology—whose number is rapidly increasing throughout the Province—it appears necessary to commence with a general summary of what has been ascertained up to the present time concerning the zoological characters and distribution in time and space of this somewhat extraordinary group of extinct organisms. By this course it is hoped that, while the foreign geologist will receive all the intimation he desires of what we are doing, the growth of science in our own country will also be promoted.

The Cystideæ were a race of small marine animals, which flourished vigorously during the Silurian period, but totally disappeared before the commencement of the Carboniferous era. They were closely allied to that interesting family, the lily encrinites, or Crinoids, and, like them, entirely covered, as with a coat of mail, by a dermal or external skeleton of thin calcareous plates, which were sometimes richly ornamented with radiating ridges or striæ. Attached to the lower extremity of the body was a short flexible stalk, usually called the column, that served to anchor the animal

securely to one spot on the bottom of the ocean throughout life; and at the opposite, or upper end, a set of arms, which, in addition to their other functions, may have assisted in the collection of food by exciting currents of water towards the mouth. This latter organ was a circular or oval aperture, situated in the side, below or near the summit, and in some species must have been also the passage through which such matter as could not be digested was thrown out. The young were developed from eggs, which were, there is good reason to believe, generated in the grooves of the arms or pinnulæ, where, as has been ascertained by actual observation, the organs of reproduction are situated in the Crinoids that exist in some of the seas of the present time.

Concerning the food, habits, or other particulars of the natural history of the Cystideæ, we can never hope to acquire any great amount of information, as the race wholly perished many ages ago, and the only evidences we have of its existence are, with few exceptions, very imperfect skeletons, which exhibit nothing except the structure of the external hard parts. It is only probable that their nourishment was derived from minute particles of animal or vegetable matter diffused through the waters in which they lived. The structure and position of the mouth are such, that they could not have been highly carnivorous, while their nearly sedentary condition would altogether preclude the capture of any prey except such as might float by chance within their reach. Animals rooted to the ground like a plant would fare ill were they organized to support life by the predacious mode only.

The fossil remains of the Cystideæ consist for the greater part of mere fragments of the plates and columns; but these, in certain localities, occur in such prodigious abundance, that they constitute the principal portion of strata of rock several feet in thickness. Of many of the species specimens of the bodies are exceedingly rare, and when these are discovered they are usually more or less crushed and distorted. While the fossil Corals, Brachiopods and Gasteropods may be collected in hundreds, few cabinets can boast of half-a-dozen good Cystideans, even in those countries where whole formations of rock are composed of the exuviæ of the race.

With respect to their distribution in time, they have been discovered in Bohemia, by M. Barrande, in beds which lie in the very bottom of the oldest rocks containing traces of animal life; and therefore, according to the present state of our knowledge of the primeval fauna, they were among the first living things that made

their appearance upon the surface of this planet. The Lower Silurian formation, in the several countries where it has been most studied, has at its base a great thickness of stratified rocks which are altogether without fossils—at least none have been discovered in them up to the present time. Then follows in conformable succession a series in which organic remains do occur, but not in any great abundance. This is the lower half of the fossiliferous portion of the Lower Silurian. In Great Britain these strata are the Lingula Flags of Sir Roderick Murchison; in Bohemia the Primordial Zone of Barrande; and in Norway and Sweden the Alum Slates, or Regions A and B, of M. Angelin, the leading palæontologist of that country. In America they have not been distinctly recognized, although it is doubtfully anticipated that the Potsdam sandstone and the lowest sandstones of the western states may be of the same age. It is more probable that some of the ancient schists in the eastern states, where a large trilobite of the genus *Paradoxides* has been found, are of the age of this "primordial zone of life." In whatever way this point may be decided hereafter, it is only in Bohemia that Cystideæ have been found so low down in the geological series. Four species have there been discovered, together with twenty-seven species of Trilobites, one Brachiopod (*Orthis Romingeri*, Barrande), and one Pteropod (*Pugiunculus primus*, Barrande), but no Crinoids.

In Scandinavia the Primordial Zone has not yet yielded traces of either Crinoids or Cystideæ, but seventy-one species of trilobites, and eight Brachiopods of the genera *Lingula*, *Orbicula*, *Orthis* and *Atrypa*, have been discovered, with one or two graptolites and a small orthoceratite, near the top.*

In England the Lingula Flags, which are regarded as the equivalents of the Bohemian and Scandinavian deposits, have furnished a very similar fauna of trilobites and rare mollusca, with one or two graptolites; but up to this date only a fragment of a crinoidal column and no Cystideans. It is also to be observed, that in none of these countries have any corals been detected in these lowest fossiliferous strata.

In the upper half of the Lower Silurian, organic remains become exceedingly abundant, and it is in this part of the geological series that the Cystideæ attain their greatest development, both in the numbers of the species and of the individuals. This deposit is

* Parallèle entre les Dépôts Siluriens de Bohême et de Scandinavie; par M. Barrande page 39 et seq.

represented in England by the Llandeilo and Bala or Caradoc groups of Murchison; in Bohemia by the stage D, containing the "second fauna" of Barrande; in Scandinavia and Russia by the Regions BC, C and D of Angelin, and the "Pleta" or Orthoceratite limestone; and in Canada by all the groups from the base of the Calciferous Sandrock up to the top of the Hudson River group.

While these rocks were slowly being deposited, the Cystideæ literally covered the bottom of the ocean in dense swarms in certain localities which were favorable to their existence, one generation growing upon the remains of another, until thick beds were formed. In Russia, Norway and Sweden, Sir Roderick Murchison* discovered them in the Pleta limestone, which appears to be of the age of the Chazy, Birdseye, Black River and Trenton limestones, packed together like "bunches of enormous grapes;" and in Bohemia M. Barrande has found them equally abundant. He says that the Crinoids and Star-fishes have left only insignificant traces, but the Cystideæ form entire beds of from one to two yards in thickness.†

In Canada they make their appearance rarely in the Calciferous Sandrock, but in the Chazy and Trenton their remains are more common, consisting however mostly of the detached plates packed together in thick strata. They are not very generally distributed, but confined to certain localities. Throughout extensive regions occupied by these formations scarcely a vestige of a Cystidean is to be found; but in other places, such as the neighbourhoods of the cities of Montreal and Ottawa, they are exceedingly plentiful. Everywhere however good specimens are rare.

M. Barrande, in comparing the European rocks of this age, observes, that in Bohemia the Cystidean zone occurs about the centre of his stage of Quartzites D, which would be also the equivalent of Angelin's group C. In England the corresponding level would be about the Bala limestone, where the principal masses of Cystideæ are found. The abundance of their remains in the Chazy and Trenton of Canada confirms the views of M. Barrande, and at the same time tends to shew that these two American formations should be paralleled with the Bala rather than with the Llandeilo. This question however cannot be decided without more perfect lists of fossils than can be at present procured.

The number of species of Cystideæ that occur in this zone are as follows, so far as I can ascertain, in these countries respectively:—

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* Geology of Russia and the Ural Mountains; by Sir R. I. Murchison, page 38.

† Système Silurien du centre de la Bohême; par M. Joachim Barrande, page 66.

Scandinavia and Russia*	20
Great Britain†	13
Bohemia, about	8
Canada	21
New York	1
	63

In consequence of the imperfection of the specimens and some confusion in the descriptions of different authors, the above numbers may not be exactly correct; but from what I have seen it appears to me that there are more than sixty species, described and undescribed, belonging to this period.

In the Upper Silurian there are in Great Britain nine species, and in Canada and New York about the same number, but none in either Bohemia or Scandinavia have yet been made public.

According to the present state of our knowledge, then, in the lower half of the Lower Silurian there are four species, in the upper half sixty-three, and in the Upper Silurian eighteen.

Very little dependance however can be placed upon numerical comparisons, such as the above, in dealing with questions relating to the Cystideæ or Crinoideæ, for the reason that new discoveries are every year being made which very materially change the aspect of these computations. For instance, six years ago only eleven Crinoids, one Cystidean, and one Star-fish, were known in the Lower Silurian of New York and Canada, but in the collection of the Geological Survey of Canada there are now twenty-one species of Cystideans, about fifty Crinoids, and ten Star-fishes, or in all eighty-one species of Echinodermata from this formation instead of thirteen.

In the Devonian formation several forms resembling Cystideæ have been referred to that group of organisms; but it remains still to be shewn that they are true Cystideans. The weight of the evidence tends to shew that the race was ushered in with the first living inhabitants of the deep—attained its greatest development in the latter portion of the Lower Silurian era, and died out about the time of the commencement of the Devonian. Of its associates in the Primordial Zone, the Brachiopoda, Pteropoda and Bryozoa remain to the present day. The trilobites held their possession of

* Bronn's Index Palæontologicus. Zweite Abtheilung, p. 181.

† On the British Cystideæ, by Prof. E. Forbes. Memoirs of the Geological Survey of Great Britain, vol. ii. part 2, p. 483 et seq.

existence until the Carboniferous period, and the graptolites disappeared early in the Upper Silurian. With the exception then of the graptolites, the Cystideæ were the first race that became extinct.

II. *The General Form and External Skeleton of the Cystideæ.*

In form the Cystideæ were either globular, oval, pyriform, conical, or sub-cylindrical, and their dimensions seldom more than one inch and a-half or two inches in length and breadth. They were protected by an external skeleton composed of flat polygonal calcareous plates, which were so accurately fitted together that they enclosed, with the exception of the arms and column, the whole of the animal almost as completely as an egg is contained in its shell. In some of the species the plates were neither limited as to their number, nor arranged according to any definite order, and in these, as the body increased in size, the corresponding enlargement of the skeleton was effected both by the growth of the older plates and the introduction of new ones between them. In many species the number of the plates and plan of arrangement remained constant throughout the life of the animal, the shell being enlarged by the continual growth of the original plates and without the addition of new ones. In others, such as the species of the genus *Pleurocystites*, both of these modes of increase prevailed, the dorsal side having the number and arrangement definite and the ventral indefinite. The growth of the individual plates appears to have been by the assimilation of fresh particles of matter throughout the whole mass, instead of by additions to the edges.

III. *The Mouth, Ambulacral Orifice and Anus.*

In the Cystideæ we find two and in some species three principal apertures through which the more important functions of the animal economy were exercised. These are :—

1. *The mouth*,—A large orifice situated on one side, usually about the middle of the body, but sometimes near either the base or the apex. In many species it was provided with a valvular apparatus, by which it was opened or closed; in others no such provision existed, or at least it has not been preserved in the fossil state. It is quite probable that in most of the species this orifice subserved the double function of a buccal and an anal aperture.

2. *The ambulacral orifice.*—This opening is always situated in or near the centre of the upper part of the body, and in the central

point between the bases of the arms when these are present. Through it the vessels of the aquiferous system and of the organs of reproduction, which were situated in the grooves of the arms, communicated with the interior. There can be little doubt also that the nervous filaments, if the Cystideæ possessed any, gained access to the arms through this passage.

Concerning the functions of these two apertures much difference of opinion has existed amongst the best naturalists, some regarding the large opening in the side as an ovarian orifice, others believing it to be the mouth. Since the discovery recently made of the ambulacral orifices of the true Crinoideæ and also of the arms of the Cystideæ, it appears to be quite certain that the latter opinion is the correct one. I shall notice this subject more at length in the next section.

3. *The anus.*—In some species there is a third small aperture, which is always situated near the apex. It is usually minute and in certain genera has not yet been observed. This orifice is designated the anus by most authors, a view of its characters somewhat supported by the fact that we know of no other function that can be assigned to it. In the species which were not provided with this opening, the excrements were ejected through the mouth, as in those Star-fishes that have no anus.

IV. *The Arms, Ambulacral Grooves and Pinnulæ.*

The arms of the Cystideæ only differ from those of the true Crinoideæ in the position which their bases occupy in the skeleton, and in the general inferiority of their development. The structure of the arms is essentially the same in the two groups, but in none of the Cystideæ do we find them of a very high degree of perfection. I propose to arrange them in the following order:—

1. Cystideæ in which the body of the arm was not developed, but only the grooves and pinnulæ. The following species are examples:

Cryptocrinus cerasus (von Buch), which in the specimens I have observed, has fourteen small plates arranged in a circle around the ambulacral orifice. Each one of these exhibits upon its surface a small irregular scar, which marks the position of the attachment of a single pinnula. No grooves are visible, but it is quite evident that this species had no true arms.

In *Echino-encrinites angulosus* (Pander), there were five or six pinnulæ, with their corresponding grooves.

In the genus *Glyptosphærites* (Müller), represented by the species *Sphæronites Leuchtenbergii* (Volborth), very slightly impressed grooves radiate from the ambulacral orifice and ramify over the surface of the body. At the end of each branch the place of the attachment of a pinnula is seen. Upon the closest examination of good specimens I have been unable to detect any indication that these grooves were occupied by an arm that was bent backward upon the body as in the genera *Apiocystites* (Forbes), and *Callocystites* (Hall). It is also quite clear that the pinnulæ were not seated upon arms of this kind, but immediately upon the surface of the plate. The grooves are not excavated but impressed; they appear as if they had been formed by several fine threads lying on the surface, while the plates were too soft to sustain their weight. In this species the pinnulæ were distant from each other and scattered over the greater part of the body. In *C. cerasus* they formed a circle around and quite close to the orifice, and in *E. angulosus* they were also confined to the apex, but somewhat scattered According to my views we have in these forms the lowest and most rudimentary condition of the radii yet seen in any Crinoideæ or Cystideæ. The ambulacral vessels issued from the interior through the orifice, and having nothing to support them, crept along the surface, sending out branches to those points where the pinnulæ arose. The main trunk of the arm, or that which bears the pinnulæ in the Crinoids, was totally absent: it was never developed. There is nothing but the grooves and the pinnulæ to indicate the existence of an ambulacral system.

2. Cystideæ in which the arms were developed, but bent backward and attached to the body. In these we perceive a structure one stage more perfect than in the several species just noticed. The arms of *Apiocystites pentrematoides* (Forbes), *Callocystites Jewettii* (Hall), and *Glyptocystites multiporus*, are all constructed upon the same type. They originate in the apex of the fossil, where their bases are all crowded together into a narrow space, in the centre of which is the ambulacral orifice. They are composed of double series of flat plates which alternate with each other, and have the usual grooves of the Crinoids along their centres. On each side of the groove is a row of pinnulæ. From the main groove smaller ones branch out to the base of each pinnula. The whole structure is exactly that of the arms of the true Crinoideæ, but not so perfectly developed. The arms of all the Crinoids have sufficient strength to stand erect, but in these Cystideæ it appears to have been otherwise, and consequently we find them not free and supporting themselves, but lying at full

length upon the surface of the body. In *Amygdalocystites florealis* and the two species of *Malocystites*, the arms are also recumbent, but their position is somewhat different. The grooves are not in the centre of the upper surface of the arms, but upon one side, and there is but one row of pinnulæ. These characters are not the results of a different structure, but are occasioned by the curious position of the arms, which do not rest with their backs in contact with the surface, but with one of their sides undermost.

3. *Cystideæ with free arms.*—The only species known is *Comarocystites punctatus* (Billings), which has not only the free arms but also the pinnulæ of a true Crinoid. It is probable that some of the small Cystideans described by Professor Forbes, in the "Memoirs of the Geological Survey of Great Britain," belong to this group. The four little prominences on the top of *Caryocystites munitus* appear to be the remains of arms which were free, and of a large size in proportion to the magnitude of the body. The genus *Pleurocystites* has two appendages which are more of the nature of pinnulæ than arms. They are composed of a double series of joints, and have the grooves bordered by small marginal plates. In this respect they exactly resemble the pinnulæ of *Pentacrinus caput-Medusæ* as figured by Miller. Although in the descriptions of the species I have called them arms, I am not at all satisfied that they are entitled to be so designated.

The distribution of the arms of the Cystideæ above given into three kinds, is not intended as a classification of the species into groups. On the contrary, we find that widely different genera, such as *Malocystites* and *Apiocystites*, have recumbent arms, and others equally far apart, such as *Echino-encrinites* and *Glyptosphærites*, with pinnulæ only, while *Comarocystites*, which agrees with the *Sphæronites* in the numerous plates of the body, has the arms free. Even in the same genus we have two of those degrees of development, for *Glyptocystites Logani* has only pinnulæ, but *G. multiporus* has both recumbent arms and pinnulæ. It is quite clear therefore that such characters are not often of more than mere specific importance in classification.

V. *The Calycine Pores or Pectinated Rhombs.*

Many of the Cystideæ were also provided with a peculiar system, consisting of pores which penetrated through the plates of the body, and probably served as media of communication between the interior and exterior, although the precise nature of their functions has not

yet been ascertained. The form and distribution of these pores vary greatly, but certain groups of species, closely related by other characters, have them arranged after a plan common to themselves, and not found in the species of other groups. Thus the genera *Prunocystites* (Forbes), *Pseudocrinites* (Forbes), *Apiocystites* (Forbes), and *Lepadocrinites* (Conrad), belong to a group characterized by a skeleton composed of a small number of plates, about twenty, which are arranged in four series. All these have three pectinated rhombs, one situated at the base and two near the apex. *Echino-encrinites* (Meyer) and *Glyptocystites* have the same number of plates, but the rhombs, although the same in general structure, are arranged in a manner somewhat different from the others: *Echino-encrinites* having two rhombs at the base and one in the upper part of the body, while *Glyptocystites* has from ten to thirteen rhombs; but two of these, in *G. multiporus* and also *G. Forbesi*, are situated at the base of the dorsal side, in a position exactly like that of the two basal rhombs of *Echino-encrinites*. In those genera with the skeleton composed of an indefinite number of plates, the pores are circular, and not clefts of considerable length, as in the others. It appears therefore that good characters for classifying the species of the Cystideæ into groups can be derived from the form and arrangement of these organs, and accordingly a classification upon this principle has been proposed by Professor J. Müller of Berlin. The outlines of his system will be given hereafter.

VI. *The Column.*

The stem, stalk or column of the Cystideæ is usually short and tapering from the body downwards. In other respects it is the same in structure as the columns of the ordinary Crinoideæ. The most remarkable form is the column of *Lepadocrinites gebhardii* (Conrad), from the Lower Helderberg rocks of the United States. It differs from all others known in having a large portion of the lower extremity composed of a single long spindle-shaped joint.

SECTION II.

ON THE AMBULACRAL ORIFICES OF THE CYSTIDEÆ AND CRINOIDEÆ.

If it were possible to procure a Cystidean with all the internal and external organs perfectly preserved, it might be easy to deter-

mine accurately the functions of the several orifices that have occasioned so much discussion among the eminent naturalists and palæontologists who have written upon the structure and affinities of these fossils. It is not however probable that a single specimen retaining even a vestige of the soft parts will ever be discovered, and we are compelled therefore to content ourselves with the next best method of conducting the investigation. The only course is to proceed by examining and comparing the offices of the ambulacral grooves and apertures of some of the existing species of Echinodermata which have been dissected by observers of good authority. In pursuance of this plan, I shall here notice briefly such points in the organization of the Star-fishes and recent Crinoids, as appear to have a direct bearing upon the subject.

I. *Ambulacra of the Star-fishes.*

The Star-fishes are not closely related to either the Crinoideæ or the Cystideæ in the structure of their skeletons, but they present the most perfect examples of Echinoderms with all the ambulacral vessels located in grooves upon the outside. The mouth is situated in the centre of the under-side of the body, and the ambulacra consist of a set of deep furrows which radiate therefrom to the outer extremities of the rays. They contain the following organs, all of which communicate with the interior by passing inward through the mouth.

1st. *The aquiferous canals*, consisting of a set of long tubular vessels extending the whole length of the furrows and entering the mouth. They are attached to, or originate in, another vessel, which forms a ring around the mouth, inside of the body. Connected with these vessels, and situated in the grooves, are two or four rows of suctorial feet, the whole constituting the most extraordinary system of locomotion known.

2d. *The nerves of the ambulacra.* These are also connected with a ring around the œsophagus, and pass out from the interior through the mouth. The main trunks lie along the bottoms of the ambulacral grooves, and send out branches to the suctorial feet.

3d. *The blood-vessels*, which also proceed from circular canals in the interior, and reach the ambulacra through the mouth.

The aquiferous canals and suctorial feet, with their nerves and blood-vessels, constitute the ambulacral system of the Star-fishes; and as all the organs are situated on the outside of the animal, and

communicate with the interior through the mouth, one of the functions of the aperture is that of an ambulacral orifice. In those species without an anus, the ova and excrements are extruded through the oral opening. In many which have an anus there are several sets of genital pores for the production of the eggs.

The following then are the apertures which in the Star-fish without an anus are all combined in one:—

1. The mouth.
2. The anus.
3. The ovarian apertures.
4. The ambulacral orifice.

In those with an anus and genital pores, the mouth has of course but two functions.

II. *Recent Crinoids.*

In the recent species of Crinoids, such as *Pentacrinus caput-Medusæ*, and the several species of the genus *Comatula*, the ambulacral grooves radiate from the mouth and are continued along the ventral sides of the arms to their extremities. At first there are five only, but these divide into ten before reaching the margin, in order to furnish a groove for each of the ten arms (see fig. 1). The grooves also send off slender branches to the pinnulæ, and they are all provided with suctorial feet, ambulacral canals, nerves and blood-vessels, as in the Star-fishes. The young however do not escape through the mouth, but the ova are developed beneath the soft skin in the grooves on the ventral side of the pinnulæ, and when the proper time arrives are set free. The vessels of the arms all enter through the mouth, and as there is always a distinct anus, it follows that this aperture has two functions.

1*st*. It is the mouth.

2*d*. It is the ambulacral orifice.

3*d*. It must also, to some extent, be regarded as an *ovarian aperture*, because in all animals there must exist a connection of some kind between the reproductive and nutritive systems. It has been demonstrated by Mr. J. V. Thompson of Cork (see Edinburgh New Philosophical Journal, 1836), that the ova, as above mentioned, are generated in the arms and pinnulæ outside of the body; and as there is no other aperture for that purpose, then it must follow that whatever may be the vessels by which a communication is effected between the ovaries and the interior, they can only pass through the mouth. For the same reason, the ambulacral orifices

of the palæozoic Crinoids (to be mentioned in the next paragraph) partake also of the nature of *ovarian* or *genital apertures.*

The structure of the Star-fishes and recent Crinoids only agrees in these respects: that both groups have the ambulacra outside of the body, and the ambulacral orifice and mouth combined in a single opening.

III. *The Palæozoic Crinoids.*

In at least a great many species of the palæozoic Crinoids we find an arrangement so different, that it almost justifies their separation into a division distinct from the recent forms. The structure of the arms is precisely the same, and there is not the least doubt that their functions were also to support the ambulacra and reproductive organs, as in *Pentacrinus* and *Comatula.* In the ventral surface however, or in the circular space surrounded by the arms, there is only one large opening, but no grooves radiating from it to those of the arms. To shew more clearly the difference between the recent and extinct species in this respect, I have constructed the following diagrams:—

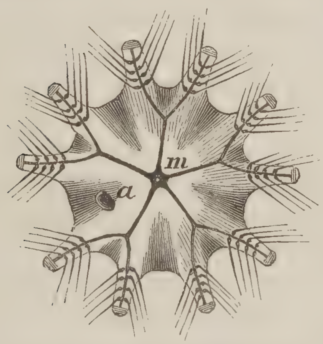


Fig. 1. Recent Crinoid.

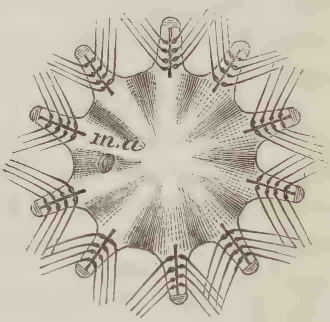


Fig. 2. Palæozoic Crinoid.

Figure 1 is a diagram of the ventral surface of a recent Crinoid with the mouth, *m*, situated in the centre, and the ambulacral grooves radiating from it to the arms. The anus, *a*, is situated between the centre and the margin, and in some of the species of the genus *Comatula* it forms a tubular projection of several lines in length.

Figure 2 is an ideal representation of the ventral region of a palæozoic Crinoid, with only one opening, *m a*, but with no grooves leading from it to the arms.

All palæontologists are agreed that this single aperture, found in all the ancient Crinoideæ, is both the mouth and the anus. It is sometimes situated in the centre, equidistant from the bases of the arms; sometimes between the centre and the margin; and in a few species, such as in *Caryocrinus ornatus* (Say), it is placed at the edge of the cup, between the bases of two of the arms. It is often level with the surface, but in many species it is in the top of a long tube, the so-called proboscis, which is frequently longer than the arms, and projects above their extremities when they are erect. The ambulacral grooves however are only found in the arms. They are not continued along the surface of the body to the mouth, as in the Star-fishes and recent Crinoids; and unless, therefore, there be some other provision made for their entrance, it is difficult to see how the ambulacral canals, nerves and blood-vessels could communicate with the interior. In those species with the mouth not elevated they might find their way along the surface, but it is improbable that they could do so without leaving some trace of their passage; and in Crinoids with a proboscis it appears impossible that this course could be followed at all. Provided therefore the usual description of the palæozoic Crinoids be correct, *i. e.*, that they have only one aperture, then their ambulacral system must have been totally disconnected from the interior of the animal—a supposition that would be contrary to all the analogies furnished by the structure of the other groups of the Echinodermata.

I have long been of opinion, that at the bases of the arms of the extinct species there were special apertures provided for the passage of the ambulacral vessels, but the evidence in my possession did not appear sufficient of itself to warrant the publication of such a view. Having had however, within the last few months, opportunities of studying a large number of specimens in the collections of England and France, I am now satisfied that there can be no doubt about the matter. It is quite certain, that a great many of the extinct Crinoids had either five, ten, twenty, or more of these openings, and that through them the vessels of the ambulacra passed from the grooves of the arms directly into the visceral cavity. While examining the magnificent collection of the Geological Survey of the United Kingdom I found many species which exhibit these apertures in a most perfect state of preservation; and upon consulting Mr. Thomas A. Huxley, F.R.S., who is profoundly acquainted with the details of the structure of all the orders of the Echinodermata,

I was delighted to find that he had already arrived at the same results, and had it in view to prepare a paper upon the subject for the "Transactions of the Geological Society." Upon my informing him however that I was also about to publish the same discovery in this decade, he in the most liberal manner made over his materials to me, and I am thus enabled to give a figure of *Actinocrinus rugosus*, which shews the course of the ambulacra under the ventral surface.

The principal difficulty in proving the existence of these orifices is to find specimens so little mutilated at the base of the arms as to exhibit the apertures with their margins uninjured. Hundreds of examples occur with large, irregular openings, but as the edges are fractured all around it is impossible to say whether or not there were originally any natural apertures. It is only in individuals which have been well preserved, and carefully collected and cleaned, that the facts can be clearly observed. In some of the species the apertures are exceedingly small, and so filled with crystalline matter that they can only be seen very indistinctly. In *Caryocrinus ornatus* (Say), for instance, there are certainly indications of the existence of minute apertures, yet in the best specimens I have seen it would be hazardous to assert it positively. In all the species of *Rhodocrinus*, *Actinocrinus* and *Platycrinus*, the apertures are in general large and easily observed. Most of the Lower Silurian specimens are in such a condition that nothing can be determined with certainty concerning any of the orifices. In one species from the Chazy and two from the Trenton limestone, all of the genus *Hybocrinus*, I have however ascertained their existence.

The following are some of the species in which I have seen clearly that these apertures actually do penetrate through into the interior of the visceral cavity:—

1. *Eucalyptocrinus decorus* (Phillips).—In this remarkable Crinoid the arms are always found closed into the niche-like divisions of the proboscis and ventral portion of the cup. It is one of those species whose structure renders a passage for the ambulacral canals through the mouth almost impossible, as the orifice is situated in the apex of a tube that projects above the extremities of the arms. In order to enter the body in that direction, the vessels, after descending the groove on the inside of the arm, could only proceed by climbing the outside of the proboscis, by which course the projecting knob of plates at the top would have to be surmounted. A more inconvenient route could scarcely be imagined, and we find that nature has provided a much shorter one. While collecting fossils in the

Niagara limestone last year, I procured at Thorold, near the Welland Canal, a specimen which had been split in two from the apex downward. I found only a portion of one of the halves. The cavity of the body and proboscis had been filled with some soft material, which, upon exposure to the weather, had totally disappeared, thus exposing the structure of the inside of the cup as distinctly as could be desired.

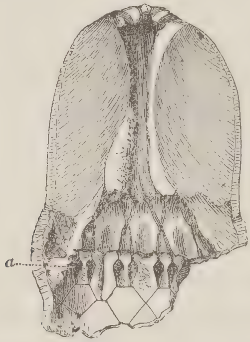


Fig. 3. Fragment of *Eucalyptocrinus decorus* (Phillips), shewing six of the ambulacral orifices.

There are two orifices at the base of each arm, and consequently twenty in all, as this species has ten arms. The specimen only retains six. They are of an oval shape, about one line in length and one-third of a line in greatest width. Each pair is separated by a small elongated ridge-like plate or process, which cannot be seen on the outside of the cup. All the inter-radials which are situated in the same level with the apertures have at each of their upper angles a sharp process, which projects inwards about half-a-line. (In figure 3, if the dotted line from the letter *a* were continued, it would cross the centres of the apertures and inter-radials here referred to.) The processes are above the line, and cannot be shewn by wood-engraving. The small plates which separate the two pores of each pair of the orifices have also each a similar process, between which and the process of the contiguous inter-radial there is a very narrow passage from the orifice upwards; and it is possible that the ambulacral canals took an ascending course by this route after gaining the interior. Upon such points however of the internal structure of the Crinoids, all that can be offered perhaps for an age yet to come must be merely conjectural. The main fact proved by this specimen is the existence of the ambulacral orifices at the base

of the arms, and that consequently it was not necessary for the vessels to climb the proboscis in order to reach the interior.

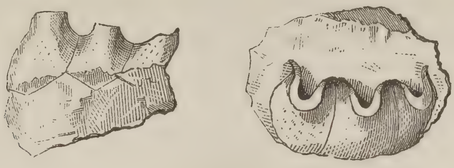


Fig. 4. Side view of a fragment of *H. pristinus.*
Fig. 5. The same, seen from above, shewing the continuation of the ambulacral grooves of the arms into the interior.

2. *Hybocrinus pristinus*, *H. conicus*, and *H. tumidus*, (Billings,) have five ambulacral orifices each, and they are formed according to a plan which will be found somewhat common among the species of those genera which have short cup-shaped or round bodies, such as *Cyathocrinus*, *Poteriocrinus*, *Dendrocrinus* and others. The first radial plate has a projection of the central portion of the upper margin, which folds round and makes a conspicuous rounded channel which descends along the inside of the plate to the interior. The upper edge has a horse-shoe form, corresponding exactly to the first joint of the arm which is seated upon it. These species shew that generally the notches which we see in the detached first radial plates of so many others are only continuations of the grooves of the arms into the interior.

3. *Rhodocrinus bursa* (Phillips).—Good specimens of this species exhibit very distinctly ten ambulacral openings. They penetrate into the interior at about one-half the height of the body, and their margins are formed on the lower sides by a semi-circular notch in the upper edge of the second plate of each of the secondary rays, and on the upper by several of the small abdominal plates. In no other species is there more unequivocal evidence of the existence of these openings, but they are accompanied by a structure which seems to indicate two sets of arms placed one above the other. Beneath the orifices there are two articular surfaces, which mark the bases of two arms; and above each pair of the orifices there is a projection, which also much resembles the base of one or two more arms. They are very accurately figured in Phillips' "Geology of Yorkshire," vol. ii. pl. v. figs. 23, 24, 25. I shall introduce one of these figures here, in order to shew their peculiar structure :—

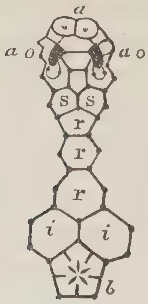


Fig. 6. One of the rays of *Rhodocrinus bursa* (Phillips).

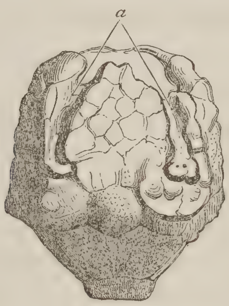
In this figure *r*, *r*, *r*, are the three primary radials; *s*, *s*, the secondaries; *a*, *o*, the ambulacral orifices; *b*, the five basal plates; *i*, two of the sub-radials; and *a*, what appears to be the place of a pair of arms. In some of the specimens this feature is exhibited so prominently that it strongly impresses the observer with the idea of two tiers of brachial appendages. It may be however that there were projecting from this part of the vault a set of large spines corresponding in numbers with the arms. *Rhodocrinus* differs in no respect from *Thysanocrinus* (Hall), provided we still depend for generic characters altogether on the structure of the cup below the point where the arms become free. But if the form of the vault be taken into account, then the English genus is different from the American.

The vault in *R. bursa* rises above the ambulacral orifices, and in fact projects a little outward over them, so that they penetrate into the side of the cup, below the margin, instead of being placed immediately above and inside of the margin, which, from the position of the arms, must be their place in *Thysanocrinus*.

4. *Actinocrinus rugosus.*—For the structure of this interesting species I am indebted to Mr. Huxley, and the figures given in the following page were drawn from a specimen in his possession.

In this species the plates are very thick, and the ventral side rises dome-shaped above the point of attachment of the arms, so that the ambulacral orifices are rather nearer the bottom than the top of the body. The proboscis is excentric, large, and not perpendicular, but projecting obliquely, so that when the arms were closed its apex probably was thrust out between two of them on one side. The mouth appears to have been closed by a number of small plates, which were no doubt so connected by an extensible membrane as

to permit of a considerable amount of dilation. The ambulacral orifices are ten in number, and enter the cup at the base of the arms. They do not however immediately penetrate into the cavity of the body, but ascend towards the top of the ventral elevation by five tunnel-like passages, which lie under the external plates and extend nearly to the apex of the dome. These passages are floored by a series of plates, which form an elongated arch under them. They do not reach the centre at the summit, but are discontinued at about two-thirds the distance from the base of the arms.



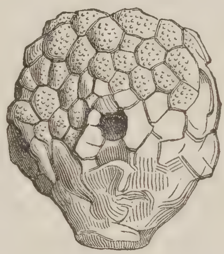


Fig. 7. A specimen of *A. rugosus*, shewing the course of the ambulacral channels from the orifices towards the summit. The exterior plates have been removed, leaving the floors of the channels visible. They terminate below the summit, at the points indicated by the lines diverging from *a*.

Fig. 8. View of the opposite side of the same specimen.

In order to ascertain whether these tubes might exist in other individuals, I procured several other specimens from the dealers in fossils and, upon removing the outer plates, found the same structure in all. Upon grinding down the summit of one of these, I find that the tubes do not reach the top of the vault, but terminate at a short distance below.

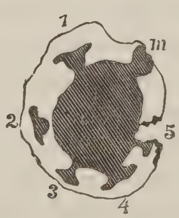


Fig. 9.

Figure 9 is a view of a section made transversely through the upper half of the ventral dome of a specimen. The unshaded border shews the great thickness of the plates of the vault. The tubes and visceral cavity are filled with soft light-brown rock. *m* is the mouth, which is cut through; at 1 is a tube, the floor of which has thinned out so, that it already communicates with the visceral cavity; *a*2 is another, with the floor remaining; 3 and 4 are in communication with the interior, although in consequence of the truncation being a little oblique, they are exposed at a lower level than the others; 5 is one with the external plates removed, leaving the bottom of the channel exposed down to the arm. The floor extends upwards four lines and a-half, and thins out just before it reaches the level of the truncation.

The important additional fact established by these specimens, and first ascertained by Mr. Huxley, is that at least in this species the ambulacral vessels, after entering the body, turn upwards towards the centre of the summit.


Fig. 10.

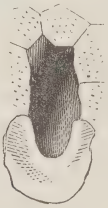


Fig. 11.

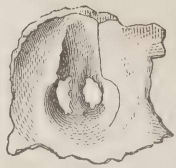


Fig. 12.

5. *Actinocrinus stellaris* (DeKoninck) has twenty ambulacral orifices which enter the body from the second or third plates of the tertiary rays. The ventral dome is very large, and at its base forms five projecting lobes, in each of which are four of the orifices. Figure 10 represents one of the lobes of a specimen in my possession. One of the orifices (fig. 10) is perfect, and shews that the margin of the upper half is formed of five small plates, while the lower side lies in the excavation in the tertiary radial plate. This excavation is simply the ambulacral groove, which is here continued into the body. Fig. 11 is an enlarged view of another orifice. A fragment of the vault of this species, which is empty, exhibits a broad rounded furrow, bounded on each side by two angular ridges running towards the summit (fig. 12). It occupies the position of one of the internal channels in *A. amphora*, and no doubt, as in that species, served to

conduct the ambulacral canals towards the summit of the ventral side.

6. *Pradocrinus Baylii* (deVerneuil*), a species which occurs in the Devonian rocks of Sabero, in Spain, has ten ambulacral apertures very clearly exhibited. The ventral surface of this fine species consists of numerous small plates, the mouth is excentric, and there are ten arms. The apertures are formed by a notch in the second plate of the secondary radials on one side, and on the other by several small ventral plates, as in *Actinocrinus stellaris*. Good specimens are in the collection of the Geological Survey of the United Kingdom, Jermyn Street. See also the figures given in the work cited.

Among the species figured in various works, the following are some that shew these apertures very distinctly :—

Fig. 13.

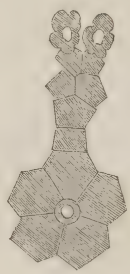


Fig. 14.

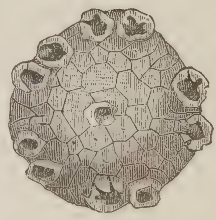


Fig. 15.

Figure 13. *Dolatocrinus lacus* (Lyon). Side view.
" 14. Diagram of one of the rays.
" 15. View of the ventral surface.

Dolatocrinus lacus occurs abundantly in the Devonian formation of Kentucky, and the above figures are taken from the beautifully illustrated Report of Mr. Sidney S. Lyon, of the Geological Survey of that State, published in 1857. (Plate iv. figs. 2, *2a*, *2b*.) There are ten ambulacral orifices, and the mouth is central, but there are no grooves from it to the arms. The generic figure given by Mr. Lyon—of which the above fig. 14 is a portion—shews all the apertures. In the same plate there are several figures of another species, *Vasocrinus valens* (Lyon), with five orifices; but of these only the grooves on the inner margins of the primary radials are preserved. All the ventral plates appear to be absent, and it

* Bulletin Geo. Soc. France, 2d series, 1850, vol. vii. page 184, plate iv. fig. 11.

cannot thus be seen whether the mouth was central, proboscidiform or otherwise, or whether the grooves of the arms were continued along the surface.

The following three figures are taken from the Report of the Geological Survey of Missouri, vol. i. part ii. plate A. Dr. Shumard, the Palæontologist of Missouri, in his descriptions of the species, expressly recognizes these apertures. He says that the example of *A. rotundus* figured "exhibits twenty-one arm-openings." (p. 191.) Of *A. Verneuilianus* he states "the vault consists of numerous small pieces, united so as to form a nearly smooth convex surface. *Proboscis*, sub-central. *Arms, unknown;* the number of arm-openings iu the specimens under examination varies from fourteen to fifteen." (p. 194.) In the same plate there are figured *A. Christyi* (Shumard), *A. Missouriensis* (Shumard), *A. pyriformis* (Shumard), and *A. parvus* (Shumard), each of which exhibits a belt of ambulacral apertures.

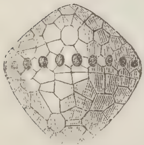


Fig. 16.

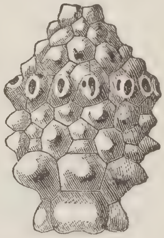


Fig. 17.

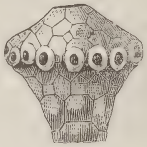


Fig. 18.

Figure 16. *Actinocrinus rotundus* (Yandell and Shumard).
" 17. *Actinocrinus Konincki* (Shumard).
" 18. *Actinocrinus Verneuilianus* (Shumard).

The above figures and remarks, if not sufficient to establish the existence of these orifices, may, it is hoped, at all events indicate that the subject is worthy of investigation. There are many species that represented in the publications of different writers which shew that there are some very interesting questions relating to the structure of the ambulacra of the Crinoids yet to be worked out, and that probably principles for both zoological and geological classification may be drawn from this source. See the following, in Pictet's *Traité de Palæontologie*, Plate XCIX. :—Fig. 1. *Solanocrinus costatus* (Goldfuss). Fig. 2. *S. Jægeri* (Goldfuss). Fig. 3. *Decamerus mysticus* (Hagenow). Fig. 2o. *Calliocrinus costatus* (Hisinger). Plate C. Fig. 2. *Haplocrinus mespiliformis* (Rœmer). Fig. 3. *Coccocrinus rosaceus* (Müller); and Fig. 7. *Gasterocoma antiqua* (Goldfuss).

IV. *The Cystideæ.*

Concerning the functions of the apertures of the Cystideæ there has always been much doubt; and in fact, at the present moment, the only point that can be regarded as established by positive evidence is, that the apical opening was the passage through which the vessels of the ambulacra issued from the visceral cavity. All the grooves of the arms or pinnulæ take their departure from it;—there are no other apertures so situated with respect to the brachial furrows that they could have subserved this function, and therefore the conclusion, that it was the ambulacral orifice, seems as well founded as could be desired. There is not the least proof, except the remote analogies furnished by the Star-fishes and recent Crinoids, that it was the mouth; and in selecting a name, therefore, the safest course is to be guided by some known character, rather than resort to the unknown.

The large opening in the side, called the mouth in this memoir, has been usually described as a genital or ovarian aperture, a view first entertained by the late Baron Leopold von Buch, and accepted with more or less hesitation by most authors up to the present time. The idea originated altogether in the supposition that the Cystideæ were armless, and consequently that the ovaries could not have been situated outside of the body. The following is von Buch's description of the Cystideæ :—

"The *Cystideæ* were natural bodies supported on a stem or pedicle, which was attached to the ground; their surface, more or less spherical, was covered by a great number of polyhedral plates, accurately fitted to one another, and between these plates were certain openings necessary for the performance of the animal functions; *but from none of these did arms proceed resembling those of the Crinoideæ. The animal was completely without arms.*

"With regard to the openings on the surface, we find in all the Cystideæ :—1*st.* That the mouth was planted in the central part of the upper surface, generally in a movable proboscis covered with minute plates. 2*nd.* That besides this mouth, and close to it, there is generally, if not always, a small anal orifice penetrating the plates, but not itself surrounded with any plates peculiar to it. 3*d.* That further towards the middle, but almost invariably on the upper half of the body on which the mouth is placed, there rises a round or oval aperture, not connected with the mouth, and often covered by a five or six-sided pyramid, which seems to be composed of as many little valves. This probably forms the ovarian orifice of the animal.

"These openings, with the exception of the mouth, *are not found to exist when arms begin to be developed from the upper surface;* and we may easily understand this when we remember that in the latter case the ovaries are carried out with the arms beyond the rim of the cup-like body, *so that a separate opening for them would be useless.* In all Cystideæ the presence of these ovarian orifices is however manifestly essential."—*Von Buch: Uber Cystideen*, Berlin, 1845. Translated in the Journal of the Geological Society, May, 1845.

It is quite clear from the above extracts that the only reason upon which von Buch founded his opinion was, that the Cystideæ are without arms. From the expressions in italics, there can be little doubt that if he had examined specimens with arms well preserved, such as some of those figured in this decade, the idea of an ovarian aperture would scarcely have occurred to him; in fact it would, to use his own words, have appeared to him 'useless.' Since therefore it is now beyond all question that the Cystideæ had true crinoidal arms, the only reason that ever suggested to any one the necessity of a genital aperture has no longer an existence, and the question remains exactly as it was before the publication of his memoir on the Cystideæ.

If then we should no longer regard it in the light of a genital opening, the next question to be decided is, What was its function? I believe that in those species which were provided with an anus, it was the mouth, and in the others both mouth and anus. The following are my reasons:—

1. In *Echinosphærites aurantium*, *Caryocystites granatum*, and many others, there is a well-defined anal aperture; and if the ambulacral orifice were also the mouth, then it would follow that the lateral opening had no function. The same would be true of the genera *Echino-encrinites*, *Apiocystites* and *Callocystites*, all of which are said to exhibit anal pores near the summit. But if the apical opening be an ambulacral orifice only, then there is no place for the mouth but in the lateral aperture.

2. The position of the organ in question is not inconsistent with the idea of its being an oral aperture, because in many of the Echinodermata we find it not only in the side but even on the under surface of the body. Thus in the Echinidæ the mouth is in the under side, and the anus either in the very highest part of the body or in the side. The Star-fish always crawls with his mouth under, and so do the Ophiura, Euryale and Comatula. The fact therefore that the lateral aperture of the Cystideæ is lower down than the anus is no proof that it is not the mouth, but directly the reverse, since it is the natural position for the organ in the class.

Even among the true Crinoids, we have at least one species with the mouth in the side, as represented by the following wood-cut, taken from the figure in plate C. of Pictet's Atlas. The genus has five basal plates and five radials; the mouth penetrates the large inter-radial, and there appears to be five ambulacral orifices. There can be no doubt but that this species is a true Crinoid, as the rays

originate in the sides and not in the centre of the ventral surface. as in the Cystideæ.

Fig. 19. *Epactocrinus irregularis* (Wirtgen and Zeiler).

3. In *Pentacrinus caput-Medusæ*, the mouth, although combined with the ambulacral orifice, has a structure similar to that of the Cystideæ. This fact is pointed out by MM. Koninck and Le Hon in their magnificent work upon the Crinoids of the Carboniferous rocks of Belgium.* The observations were made upon a fine specimen captured by a fisherman in the harbor of Moule, Island of Guadaloupe, and sent by Dr. Duchassaing to M. Michelin. The following is Duchassaing's description of the mouth :—

"The mouth of the Encrinite is surrounded by five lips, and can be seen only when these five lips are opened. It then appears as a small round aperture about two lines in diameter. The lips are not free, and can be opened to the extent of about three lines. They are adherent to the five furrows which departing from the commissures are prolonged to the circumference of the disc. Mastication is effected, not by the mouth, but by the lips, which are armed to that effect with small stiff spines. As to nourishment, I found the debris of small crustaceans."

Upon the above extract, MM. Koninck and Le Hon make the following remarks :—

"It is perhaps well to observe here, that it results from the remarks of M. Duchassaing that what he calls lips are veritable triangular valves, hard, and armed at their points and internal surfaces, and designed to hold and crush Crustaceans and other animals upon which the *Pentacrinus* appears to feed.

"They have exactly the same form as the ossicles which in the Cystideæ cover the aperture which L. von Buch has considered as an ovarian orifice.

"We have no doubt that the illustrious palæontologist whose recent death science deplores, did not recognize the true function of that opening. We are persuaded that it served the same purposes as those which have been observed iu *Pentacrinus*. Our conviction is so much the more profound that we have never been able to discover upon the triangular valves of the Cystideæ the least trace of a perforation, and that those which cover the mouth of *Pentacrinus* offer nothing more.

"It would be besides very extraordinary that these calcareous plates whose position and form are perfectly identical in these animals, belonging to the same class, should

* Recherches sur les Crinoids du Terrain Carbonifère de la Belgique. Par L. De Koninck et H. Le Hon, 1844; page 33 et seq.

be designed for such very different purposes as would result from the adoption of the opinion of L. von Buch, on the one hand, relative to the use of the triangular plates of the Cystideæ, and, on the other, from the direct observations made by Dr. Duchassaing."

From the above remarks, it is evident that MM. Koninck and Le Hon, who have profoundly studied the Crinoideæ, are of opinion that the ovarian pyramid of the Cystideæ is the exact homologue of the buccal apparatus of *Pentacrinus*, a view in the correctness of which I entirely concur. The only difference is that in *Pentacrinus* the ambulacral orifice with its grooves is combined with the mouth and its pyramid of valves, while in the Cystideæ they are separate. Von Buch was of the opinion that the five valves of the Cystideæ were perforated by five minute pores which were the ovarian pores. The organ would then present a greater resemblance to the ordinary arrangement of the reproductive system in the Echinodermata. In most of the families of this class when the ovaries are contained in the visceral cavity, there are many of them, and they have their orifices disposed according to the radiated division of the body. Thus in the Echinidæ there are five ovarian pores, sometimes it is true, reduced to four in the abnormal forms; in the Blastoidea there are five, in the Ophiuridæ ten, and in many of the Star-fishes five or ten.* It is thus contrary to analogy that when an Echinoderm has the reproductive system included in the cavity of the body, there should be but one genital opening.

4. If we consider the relative dimensions of the several apertures, we find that in general the mouth is larger than the anus. Although in the fossil Echinidæ the anal aperture often appears to be as large as the oral, yet this is owing to the destruction of a portion of it. In the living specimens the opening is covered over with the exception of a mere pore, while the mouth is of a large size. In the Star-fishes, wherever an anus exists it is always many times smaller than the mouth. In *Glyptocystites multiporus* the apical aperture is only one-tenth the size of the lateral opening; in *Malocystites Murchisoni* one-ninth; in *Echino-encrinites angulosus* one-ninth; in *Hemicosmites pyriformis* it consists of a minute three-rayed fissure (see the beautiful figure in plate iv. fig. 5, *Müller, Uber den Bau der Echinodermen)*; in all the species of *Pleurocystites*, although it has not been observed, yet the structure of the parts proves that

* See the figures of the genital pores of *Asteracanthion rubens* and *Solaster papposus*, Plate xii. *System der Asteriden*, von Müller und Troschel.

it must be exceedingly small. The same may be said of almost every Cystidean that has been described and figured: the lateral aperture is ever the largest, and when it is considered that the one in the apex, whether it be the mouth or not, always receives the ambulacral vessels by which its capacity is further diminished, the argument has still greater force.

5. The objection that it is contrary to analogy that the mouth of an Echinoderm should be situated any where else than in the central point where the grooves meet, is not borne out by the facts, because in a vast number of species of Crinoidea, the group most nearly related to Cystidea, it is not so placed. The grooves do not come near the mouth in the palæozoic Crinoids, and therefore the analogy wholly fails.

6. With respect to the bearing of the arrangement of the apertures of the recent Crinoids upon this question, there appears at first sight to be some difficulty, as in these there are two orifices, one of which not only receives the ambulacra, but is also the mouth, while the other is said to be the anus. If we were to be guided altogether by this analogy, the lateral opening of the Cystideæ would be, at least in some species, the anal aperture. There is however a great difference in the structure of the two groups. Any one who will take the trouble to examine, the figures of the species given in most elementary works, will see that the rays of *Pentacrinus caput-Medusæ* spring from the very base of the body. The first radial plates of all the rays rest upon the upper joint of the column, and the others follow in succession up the sides. If the point of the attachment of the column be the dorsal side, then the rays are developed from the centre of the back. The same structure occurs in *Comatula*. But in the Cystideæ it is the very reverse: the rays spring from the centre of the ventral side. The whole of the cup of the Crinoid is radiated, but in the Cystidean it presents no trace of a radial arrangement: all below the apex is unradiated; the bases of the arms are crowded together, so that they all originate in a narrow space upon the upper side of the body, where they surround the ambulacral orifice. The first primary radial plates, which in *Pentacrinus* rest upon the column, are in the Cystideæ transferred to the opposite pole of the body, and are there represented by the circle of plates which surround the ambulacral orifice. This view of the structure of the Cystideæ was first put forth by Volborth, and afterwards adopted by Professor J. Müller of Berlin. Neither of those authors however

appear to have been aware of the existence of special orifices in the Crinoids for the passage of the ambulacral vessels, and hence they still regarded the apical aperture as the mouth. Volborth says:

"All the Cystideæ were, like Crinoids, provided with articulated arms; and this statement is not mere hypothesis, but is the result of philosophical induction from distinct well-grounded facts, determined by observation—by the actual presence of arms in some species, and the presence of tentacle furrows in others. The Cystideæ were also *true Crinoids*. Either in the young state or throughout life they were attached by an articulated stalk, or by a pedicle, either to the bottom of the sea or to foreign bodies. They had articulated arms which, as in Crinoideæ, proceeded from the dorsal pole of the cuticular skeleton. Diametrically opposite to the orifice of the pedicle is placed the buccal orifice, and generally close to it is the sub-central anal orifice. The cup differs however from that of the Crinoids, by such a predominance of the dorsal side over the ventral, that the latter is often reduced to a minimum, consisting only of the orifice of the mouth, so that the arms appear to be much nearer the mouth than is the case with Crinoids."—*Volborth on the Arms of Cystideæ.* Trans. Min. Soc. of St. Petersburgh, 1845—6.

Professor Müller, whose extraordinary researches in the department of the development of the recent Echinodermata have never been excelled, says:—

"The development of the antambulacral side of the radii in Crinoids takes place either from the very base of the calyx, or from its circumference, or in the neighborhood of the mouth, as in most *Cystideæ*. In the latter case the calyx presents no radial arrangement of plates from the base to the immediate neighborhood of the mouth; it begins only at the mouth in the oral arms, whose ambulacral grooves however lead to the mouth, and, like the articulated antambulacral surface of the arms, present no traces of the general plan of the Echinoderms. Hence it is intelligible why, so long as the Cystideæ were held to be armless, the radial arrangement of the Echinoderm was unrecognized."—*Uber den Bau der Echinodermen*, p. 55. Translated by Mr. Huxley in the Annals of Natural History, 2d series, vol. xiii. p. 242. April, 1854.

Professor Müller terms the dorsal side of the arm of a Crinoid antambulacral, thereby distinguishing it from the ventral side, whch is grooved and holds the ambulacra. The genital and ocular plates of the sea-urchins are also antambulacral, but they are few in number, and usually confined to one spot in the centre of the back; and therefore the principles contained in the above extract may be applied to shew that the Cystideæ are not so nearly related to the recent Crinoids as they are to the palæozoic species.

a. If we take a sea-urchin and placing it with the mouth upwards, which is the usual position of that organ in the Crinoids, then imagine a plane to be projected horizontally through the circular area occupied by the antambulacral plates, the whole of the body of the animal will lie above the plane. Its skeleton is composed

altogether of ambulacral and interambulacral plates, with the exception of the small space in the back, consisting of the ocular and genital plates.

b. If a similar plane be extended through the lower edges of the first primary radials of *Pentacrinus caput-Medusæ*, the body, as in the sea-urchin, will lie above it; but then it is covered at the sides by the plates of the rays, and on its upper surface by the ventral plates, all of which are antambulacral.

c. In such Crinoids as the species of *Poteriocrinus* and *Cyathocrinus*, which have two rows of plates below the radii, a plane through the lower points of the primary radials would have about one-half of the body below it, and the other half above. Here we see a tendency in the radiated skeleton to transfer its base from the dorsal to the ventral side; and it is interesting to perceive that in Crinoids of this structure we first find species which indicate their approach to the Cystideæ by the exhibition of poriferous areas, which are at least analagous to the pectinated rhombs of that group. These exist in *Porocrinus conicus* (Billings) of the Trenton limestone, and *Caryocrinus ornatus* (Say) of the Niagara group.

d. The Cystideans with a definite number of plates, such as the genera *Echino-encrinites*, *Glyptocystites*, *Apiocystites* and *Prunocystites*, are certainly more nearly related to the Crinoids than those with the body covered by a large and indefinite number, as, for instance, *Echino-sphærites aurantium.* The number five, so dominant in the arrangement of the parts of the body in the Crinoids, is apparent in these genera, although no trace of it can be seen in the sphæronites. Thus in *E. angulosus* (see plate iii. fig. 1*b*) there are four basal plates, but one of these is hexagonal, and can be divided so as to make two, which would be pentagonal like the other three. Above the basal plates are three other series of five each. It may be granted that the plates of the fourth series are the homologues of the five first primary radials of *Cyathocrinus planus* (Miller), which form a circle round the margin of the cup. When closely examined it will be seen that in both the Crinoid and the Cystidean these plates are notched in their upper margins by the ambulacral grooves; and it is therefore probable that they are strictly the homologues of each other.

If now in these two species we draw the plane as before, about one-half the body of the Crinoid and nearly the whole of the Cystidean will lie below it. The radiated skeleton in *E. angulosus* has ascended from the base to the apex of the body, and it is there

compressed into so small a space that there is no longer any room for the mouth in its centre. The organ is crowded outside of the circle of radial plates, and lies lower down in the body. If the arm-bearing plates of *Caryocrinus ornatus*—a species admitted to be almost a Cystidean—were thus drawn together into the centre of the ventral surface, the mouth would certainly be left outside, because it is situated in the margin, between two of the arms. It would not however on that account change its nature and become a genital aperture.

c. In all the species with an indefinite number of plates the difference is still greater. If we extend the plane through the base of the arms in *E. aurantium*, we would have the very opposite of what occurs in the instance of the sea-urchin. The body would form a large globe-like expansion below the plane, while in the sea-urchin it lies altogether above. The Cystideans of this type must be regarded as the extreme in one direction, and the Echinidæ the extreme in another. Prof. Müller says:—"In an Echinoderm which remains antambulacral quite up to the mouth, and develops arms only from the oral part of the calyx, we have at its maximum that condition which in the *Echinidæ* is at its minimum. To borrow the phraseology of the 'Natur-philosophie,' we may say that the calyx of a *Pseudocrinites*, *Agelocrinites*, *Echinosphærites*, *Echino-encrinites*, is the apex of an *Echinus;* it is however an expansion of the apex large enough to enclose the whole of the intestines of the animal, while in the *Echinus* these are invested for the most part by the ambulacral zone of the perisoma."—*Uber den Bau der Echinodermen*, p. 16; *Annals of Natural History*, 2 ser. vol. xiii. p. 9.

If now we place the above forms in series arranged according to the greater or less concentration of the antambulacral side of the rays towards the centre of the back, all the Crinoids would lie between the Echinidæ and the Cystideæ. Thus:

In the Echinidæ the antambulacral radiated skeleton is absorbed into the middle of the back.

In *Pentacrinus* and *Comatula* it is also strongly concentrated, but covers the whole of the back and sides.

In *Thysanocrinus* (Hall), a genus which appears in the Trenton limestone, the unradiated space at the base of the cup is larger than it is in *Pentacrinus*. There are two series of plates below the first primary radials. There is then in this genus a tendency in the radiated portion of the skeleton to depart from the centre of the back and take its origin from the upper part of the body.

When we examine a specimen of any species of *Cyathocrinus*, we perceive another step in the same direction. There are, as in the last genus, two rows of plates below the radii; but, in addition to this character, the ventral side of the animal does not rise above the upper margins of the first primary radials. The radiated skeleton forms a belt round the upper part of the body, and *Cyathocrinus* is therefore nearer to *Echino-encrinites* than is *Pentacrinus*, because the bases of the rays are nearer the ventral side.

Many other examples might be given in illustration of this point, were it necessary. The general conclusions I draw from the whole of the above are, that when we compare the recent and ancient Crinoids with the Cystideæ, the latter two are seen to be the most nearly related upon the whole—that those genera with two series plates below the radii are the nearest to the Cystideæ, and that the genera with the rays developed from the base are the most distant of the Crinoids, the Echinidæ being still further away.

If these conclusions be correct, then the apertures of the Cystideæ should be more properly compared with those of the palæozoic than with those of the recent Crinoideæ. These latter have no special ambulacral orifice, the function being exercised through the mouth. But the palæozoic Crinoids have the ambulacral orifices separate from the mouth, and so it would most probably be in the Cystideæ.

Classification of the Cystideæ.

The following passage, extracted from the memoir of Professor Müller on the Structure of the Echinoderms, contains the outlines of a system of classification which will most probably be generally adopted. It should be borne in mind that he was not aware of the existence of the ambulacral orifices in the Crinoids, otherwise no doubt some portion of his paper would have been directed to their examination :—

" *Cystideæ.*—Among the Crinoids the *Cystideæ* of L. von Buch form a group which is distinguished by the inclusion of the genital organs, together with the other organs, in the calyx. In the *Pentacrinites* and *Comatulæ* on the other hand, the sexual organs are attached to the pinnulæ of the arms; in those Crinoids which have only one calycine opening (mouth), as *Actinocrinus*, *Platycrinus*, &c., the exclusion of the sexual organs from the calyx is at once rendered probable by the

absence of any aperture corresponding with them. The *Cystideæ*, on the other hand, have at least two and sometimes three apertures to their calyx, one of which, distinguished by its valvular closure, is found in no other Crinoids than the *Cystideæ*. L. von Buch has determined that this valvular pyramid is the genital aperture.* We owe to him the recognition of the close alliance of these forms with the Crinoids, and at the same time of their peculiarities, the exact analysis of their calyces, and the exposition of their genera. That they are not armless, as had hitherto been generally supposed, was first observed by A. von Volborth, who discovered the arms in *Echino-encrinus angulosus* and *striatus*, subsequently in *Echinosphærites aurantium*, where they proceed from the mouth. The figures of the Duke of Leuchtenberg, and those of Volborth of *Sphæronites Leuchtenbergii* and *Protocrinites oviformis* would indicate the presence of arms in these also, although they have not been actually obtained. In fact, branched grooves run from the mouth over a great part of the calyx; the branches of the grooves however end in papillæ of the calyx, which must be regarded as points of origin of arms—a circumstance so much the more remarkable, as it would follow that the arms of these *Cystideæ* must have had a position far removed from the mouth (Verhandl. d. Konigl. Mineralog. Gesellschaft zu Petersburg, 1845-6, Petersb. 1849). A specimen of *Sphæronites Leuchtenbergii* in von Buch's collection agrees exactly with these figures. When, in his second essay, L. von Buch founded the order *Cystideæ* (1844), the oral arms of *Echino-encrinus* were already known. He did not regard them as Crinoid arms, but called them feelers. With a correct foresight he even then arranged the *Pseudocrinites* and *Agelocrinus*, with long arms passing from the oral part of the calyx, among the *Cystideæ*, but was not inclined to consider these processes as true arms. He had even in 1840 termed the remains of the three arm-like processes in *Hemiscosmites* arms or proboscides, but was led away from a just comprehension of their nature by comparing them with oral tubes.

"In his beautiful monograph on the British Cystideans (Mem. Geol. Survey, t. ii. Lond. 1848) Forbes has increased the number of forms with oral arms. He divides the *Cystideæ* into,—1*st*, those with arms: *Pseudocrinites*, *Apiocystites*, *Agelocrinites*—2*nd*, those with

* In my copy of Müller, "Uber den Bau der Echinodermen," the following sentence follows here:—"*Eine Vermuthung, die freilich nicht sicher beweisen werden konnte,*" which may be thus rendered: "*An opinion which surely cannot be positively proved.*" Müller appears therefore to have believed that Von Buch's demonstration was not complete.

oral pinnulæ: *Prunocystites*—and 3*rd*, armless forms: *Caryocystites* and *Sphæronites;* to which latter the British form *Echino-encrinus* is added. Forbes considers that the arms observed by Volborth in the Russian species of *Echino-encrinus* are oral pinnulæ. The oral arms of *Echino-encrinus* and *Prunocystities* are articulated in two series. Volborth observed that in the former they are beset with small plates upon their ambulacral surfaces, which he calls tentacles, remarking that pinnulæ are absent. These plates have the characters of marginal plates, which in the Crinoids (*Pentacrinus*) occur on the arms as well as on the pinnulæ. In *Echino-encrinus angulosus* the remains of six arms were present. That this number does not agree with the five depressions which usually surround the mouth is explained by the fact, that the number of these facets varies; Von Buch states that there are five or six; and I possess a specimen with eight round depressions about the mouth, which are united with the mouth by grooves. *Echino-encrinus striatus* possesses, according to Volborth, together with a very much narrower pointed oral extremity of the calyx, only two much larger opposed oral arms, which have the same structure as in *Echino-encrinus angulosus.* From their relations, however, it is probable that these are not pinnulœ, but arms; for it is not usual for pinnulæ to be isolated. If they both belong to a single ambulacrum how are we to imagine a single ambulacrum in this locality in the immediate neighbourhood of the mouth? If, however, they belong to two different ambulacra, they can, as solitary structures, be only arms.

"The arms of *Echinosphærites aurantium*, Wahlenb. (*Sphæronites aurantium*, His.) have essentially exactly the same relations as Volborth has described and figured. In such well-preserved specimens as now lie before me, the origins of three articulated arms at the oral region of the calyx are recognizable. The five uppermost calycine plates are raised into a three-sided pyramid transversely truncated above, whose obtuse edges are prolonged into the arms. Two sides of the pyramid are broader than the third. The sutures between the five pieces are so disposed that two of them are situated upon the broader side of the pyramid, the three others in the obtuse edges. Two supplementary pieces, however, are added to the five principal portions of the pyramid, and extend from the calyx into two of the angular sutures. The pore-grooves of the plates of the calyx extend only on to the lower portion of the circumference of all the seven pieces. The

arms immediately subdivide again. From the oral aperture grooves beset with marginal plates, pass on to the arms. For the rest, the division of the arms shows that they are arms, and not pinnulæ. Whether these arms, like those of a few other Cystideans, as *Pseudocrinites*, were provided with articulated pinnulæ, cannot be decided, since they are broken short off. Whether the *Caryocistites* possessed arms is not as yet known, but it can hardly be doubted, since they are not certainly distinguishable from *Echinosphœrites*.

"In *Hemicosmites* three of the six uppermost plates of the calyx are provided with an insection, which arises from the tri-radiate median calycine opening. Each of the insections is continued into a groove; the groove terminates after a slight expansion in an elevation of the calyx which served for the attachment of an arm. The elevation no longer lies on the plates of the uppermost, but upon three of the plates of the second series. The elevation exists only in specimens which are not worn down, and is beautifully obvious in a specimen which M. Ewald has sent me. The tri-radiate clefts of the calyx, and the calycine grooves continued from them, are covered with minute plates which readily fall off. In the specimens figured by L. Von Buch, they are still perfect, and form a fine series of plates from the mouth to the ventral surface of the three arms. In this series again, three delicate grooves are distinguishable, as in *Echinosphœrites aurantium*, which correspond with the subjacent clefts of the large plates of the calyx and their grooves. In the always much worn specimen of *Cryptocrinites cerasus*, no indications of arms have hitherto been observed.

"Forbes regards the *Cystideæ*, like the *Blastoidea*, as sections of the Echinoderms different from the Crinoids. The *Sphæronites* were already arranged among the Crinoids by reason of their stalks before their arms were discovered, and we now have still more reason for considering this to be their true position. Volborth and Rœmer consider the *Cystideæ* as a group of Crinoids, which is also my own view. The position of the the arms however, must not be regarded as one of their characters; for in *Sphæronites Leuchtenbergii* and *Protocrinites oviformis* the arms were situated far away from the mouth, as in the other Crinoids.

"The suctorial feet of the Cystideans were unquestionably placed as in *Pentacrinus*, on the ambulacral side of the arms and in the calycine grooves. In the introductory part of this essay however, it has been demonstrated to be contrary to all analogy, that

suctorial feet should exist in any Echinoderm upon the antambulacral side of the persoma from the apical end to the arms, or between the ambulacral radii. In the *Cystideæ* therefore, the whole calyx, with the exception of the calycine grooves, is to be regarded as anambulacral.

"The genera *Pentacrinus*, *Caryocrinus*, and most Cystideans are distinguished among the Crinoids by the existence of very peculiar pores in the anambulacral plates of the calyx. *Pentacrinus* alone has afforded the opportunity of an exact investigation of these pores. I have described and figured them in the essay upon *Pentacrinus*.

"The interambulacral (interpalmar as well as intrapalmar) calycine pores of *Pentacrinus* pierce the ventral calycine plates, and lead beneath the inner membrane of the calyx. They possess no soft external prolongations. In contrast with the ambulacral calycine pores for feet, these may be called anambulacral calycine pores. Their signification is not understood, only it is certain that they are not passages for feet. A comparison with the respiratory pores of the *Asteridæ* suggests itself; soft tubes project from these, with regard to which Ehrenberg has shown (and I can confirm his statement by my own observation,) that they are cæca, which are indeed connected wiih the abdominal cavity, but are perfectly closed externally.

"The calycine pores of *Caryocrinus* are equally without relation to the arms; and thence, though differently distributed, resemble the anambulacral calycine pores of *Pentacrinus*. They occupy the antambulacral part of the calyx behind the arms as far as its base.

"Most Cystideans (*Cryptocrinites cerasus* excepted,) possess calycine pores, which are distributed over a greater or smaller part of the calyx without radiation and in a very peculiar manner. In those forms with calycine grooves, as *Protocrinites* and *Sphæronites Leuchtenbergii*, these pores again appear to be anambulacral, since, like the anambulacral pores of *Pentacrinus*, they are disposed in the areas external to and between the ambulacral grooves; here however, their distribution is far wider, since they extend as far as the base.

"Two principal divisions have been made, according to the distribution and combination of these pores:—

"I. Cystideans with pore-rhombs. The pores are disposed in rhomboidal figures, the one-half of which belongs to one plate, the other to its contiguous neighbour. Every two pores of these rhombs appear to be invariably united by canals or grooves,

which are visible either upon the outer or on the inner side of the plates, in such a manner that the united pores belong to two different adjacent plates.

" *a.* Pore-rhombs without external connexion of the pores. *Hemicosmites* and *Caryocrinus ;* in *Hemicosmites* the combining grooves are according to Volborth, upon the inner surface of the plates.

" *b.* In *Echinosphærites granatum*, Wahlenb. (*Caryocystites granatum*, v. B.), the pores are united by bands projecting externally, which contain the connecting canal of the pores, and this canal is always a single one between each pair of pores, or even a series of pores.* The more importance is to be attached to this circumstance, as the number of the calycine plates, even of the basal plates in *Caryocystites granatum*, varies, so that some specimens possess more superimposed plates than others, and even specimens with five basal plates are not rare. According to the arrangement of the plates, I do not think that *Caryocystites* and *Echinosphærites* could be separated.

" A form nearly allied to *Caryocystites granatum*, observed by M. Beyrich (Drift [*Geschiebe*] near Berlin), the plates of whose calyx are more numerous, is distinguished by the bands which unite the pores belonging to an entire series of pores, which penetrate the entire thickness of the plates, so that the series of pores appear also upon the inner surface of the plates. Something similar may also be observed in many specimens of *Caryocystites granatum*, inasmuch as the canals of the bands not unfrequently also exhibit clefts here and there between the terminal pores. These clefts may indeed be readily explained by the grinding down of the canals; the occurence of the regular rows of pores in the species above mentioned, however, leads us to question whether they always have this origin.

" *c.* In *Echinosphærites aurantium* and *E. aranea* every two pores of two plates are not uncommonly connected by one, usually by two canals, which are recognizable upon the outer surface of the plates; *Echinosphærites testudinarius*, included by Von Buch in the ill-defined genus *Caryocystites*, is an elongated Echinosphærite. Its pore-rhombs agree more closely with the previously-named species than with *Caryocystites granatum*, though the number of the pore-canals between every pair of pores is in some localities still greater.

* .... und dieser Canal ist immer ein einziger zwischen je zwei Poren, oder selbst einer Porenreihe.

In fact, we not unusually observe not only two, but three or even four conjoined canals, which open at both ends into a pore, and are so connected.

"*d.* The genera *Echino-encrinus*, *Pseudocrinites*, *Apiocystites*, *Prunocystites*, are distinguished by possessing only a few pore-rhombs—fragments of the system—which however are here justly termed pore-rhombs. In *Echino-encrinus angulosus* and *E. striatus* there can be no doubt that the elongated pores of these rhombs are clefts which penetrate the whole thickness of the plates. Forbes remained in doubt with regard to these pores, and was inclined to interpret the 'pectinated rhombs' as the situation of ciliary organs comparable with the ciliated epaulettes of the larvæ of *Echini*. Seeing the very problematical nature of all pore-rhombs, and of all non-ambulacral pores of the Crinoids in fact, the supposition that the cilia are connected with the pores and pore-canals is not to be excluded.

"The number of the pore-rhombs in the *Echino-encrinites* appears to vary, and *Echino-encrinus granatum*, Volb., would appear to be only such a variety of the *E. angulosus*.

"II. Cystideans with double pores upon the calycine plates, which belong not to two different plates, but to the same. The plates are facetted, and each facet possesses two closely approximated pores. Here belongs a small group of Cystideans, which, since it consists of many genera, might be called *Diploporitidæ (Diploporiten)*. The genera included in it are :—

"1. *Sphæronites pomum*, His., type of a peculiar genus, which may retain the name of *Sphæronites*, as opposed to the *Echinosphærites* with pore-rhombs.

"2. *Protocrinites (P. oviformis*, Eichw.).

"3. *Sphæronites Leuchtenbergii*, Volb., type of a peculiar genus, which may be termed *Glyptosphærites*. That the Russian *Sphæronites pomum*, Leuchtenb., or *S. Leuchtenbergii*, Volb., is not the Swedish *S. pomum*, Volborth thought probable from Gyllenhal's account. The specimens of the Swedish form in the Mineralogical Museum of this place put this beyond doubt. There are no calycine grooves on the true *Sphæronites pomum*, His.; on the other hand, the five outermost calycine plates are elevated into a triangular pyramid, truncated at the mouth, as in *Echinosphærites aurantium;* the edges of the pyramid are broken off in all the specimens, and leave a doubt as to the form of the arms which were probably present. The base of the calyx is transversely truncated, and very broad in relation to the diameter of the calyx; it consists of six to seven pieces.

"The relation of a few other *Diploporitidæ* to these genera is still unknown. Many of the Cystideans described by Forbes, and enumerated by him among the *Caryocystites*, viz. *C. Litchii* (F.), *C. pyriformis* (F.), *C. munitus* (F.), do not belong to the genus *Caryocystites* (von Buch), being rather *Diploporitidæ* allied to *Sphæronites pomum*, which require further investigation."

SECTION III.

DESCRIPTIONS OF THE LOWER SILURIAN SPECIES OF CYSTIDEÆ OF CANADA.

Genus PLEUROCYSTITES, Billings.

(*Canadian Journal*, vol. ii. p. 250, 1854; *Geol. Survey of Canada, Report*, 1857, p. 284.)

Generic Characters.—Body, oval, flat; dorsal side composed of large polygonal plates; ventral side almost entirely occupied by a large oval space protected by an integument of numerous small plates; arms or pinnulæ, free, two in number, articulated in two series; mouth, situated at the base on the left side; a small aperture near the apex; ambulacral orifice not yet observed; pectinated rhombs three, one in the lower half of the body and two in the upper half; column, short and tapering. Generic name from *pleuron*, a side.

The following is the arrangement of the plates:—The pelvic or basal plates are four in number; the dorsal pair pentagonal, and forming by their upper sloping sides a broad re-entering angle, in which is supported a large hexagonal plate belonging to the next series; the other two pelvic plates are situated one on each side of the dorsal pair, and partly beneath them; they do not unite on the ventral side to form the cup-shaped pelvis of the ordinary cystideæ, but spread out wing-like from the sides of the column; only a small slender projection of these plates extends round so as to meet on the ventral side. (Pl. i. fig. 1*c*.)

In the second series there are five plates; two of these are situated at the lower outer angles of the body, and from their position in the same level with pelvic plates, appear to belong to that series. They are however the exact homologues of the two plates which support the mouth in such genera as *Echino-encrinites*, *Apiocystites*, *Glyptocystites*, and others of similar structure, but separated and thrust out of

their normal position by the introduction of the area of small plates. The other three plates of the second series form a regular row across the body above the pelvic plates. The central one is hexagonal, it has one-half of the posterior pectinated rhombs on the right lower side, and is flanked on each side by a large heptagonal plate.

The third series consists of four large plates, elongated vertically; one of these, situated on the right hand of the centre of the back, is pentagonal, and next to it, on the left, is another of nearly the same form, but made hexagonal by the truncation of one of the upper angles. These two plates are narrowed above to correspond with the decreasing dimensions of the body, which here begins to contract. The other two plates of this series are either heptagonal or slightly octagonal, and at their upper extremities they fold around the body and unite on the ventral side by narrow projections, which arch over the area of small plates. Above the third series are ten smaller plates, which close the summit and form a solid support for the arms.

The ventral side, as before mentioned, is mostly occupied by an area of small plates (see plate i. fig. 1*c*, and plate ii. fig. 1*b*) which are altogether of a different character from those of the dorsal side. They vary greatly in size in the different species; for instance, in *P. squamosus* there are several hundreds of them, and in *P. filitextus* only about forty or fifty. The margins of the dorsal plates being folded over, form a solid smooth border around the whole space, and to this border the small plates do not seem to be connected. According to my view, the whole of the oval space on the ventral side surrounded by the border, was covered by a flexible integument, strengthened by the small plates, and these cannot therefore be regarded as normal plates in the sense in which the term is used in describing genera of Crinoids or Cystidea, but rather as the remains of a partially calcified dermal covering for a part not protected by the true skeleton. It follows that in this genus the dorsal side is composed of a definite number of plates, arranged according to a permanent plan, and in this respect is related to that group to which *Echino-encrinites* belongs; while the ventral side, by the indefiniteness of the number and arrangement of the plates, is more like the body of a Sphæronite.

The mouth is situated on the left hand side of the base, and opens out through a notch excavated in the border. In most specimens the sutures between the plates cannot be detected in the border, owing to the close manner in which they have been anchylosed. It can be seen however, that if the two anterior basal plates were

folded round and brought up into their proper position, the mouth would lie partly in the suture between two of the plates of the second series, which is its position in many of the ordinary Cystideæ which have the definite number and arrangement of the plates.

The ambulacral orifice probably lies in the apex in the bottom of the groove between the two arms, and must be exceedingly minute, as I have been unable to detect it in several specimens that I have disarticulated for that purpose.

The anal? aperture is also very small, and situated on the anterior side, close to the apex. It consists of a small rugged notch in the edges of two of the small plates, below the arms.

The arms are articulated in two series, and the ambulacral groove is continuous from one to the other across the space between their bases. On each side of the groove is a row of small marginal plates, two or three to each joint of the arm.

The pectinated rhombs are three in number; one of them is placed half on the right dorsal basal plate and half on the large hexagonal plate of the second series; the other two are also situated on the dorsal side, one upon the left pair and the other on the right pair of plates of the third series. Of these two rhombs the left one is the larger in all the specimens I have seen.

This genus was first discovered in the Trenton limestone at the city of Ottawa, and afterwards at Montreal in the same rock. In 1856 Mr. Richardson found one species in the Hudson River group at Anticosti. In the Museum of Practical Geology, Jermyn Street, London, are specimens of a species, *P. Rugeri* (Salter), collected in the Caradoc formation of Wales; and M. Barrande informs me that a species, which appears to be referable to the genus, occurs in his Étage D, in Bohemia, the equivalent of the Landeilo and Caradoc of Britain, and of the Trenton and Hudson River groups of America.

The species are so closely allied, that there is much difficulty in defining them; yet I am satisfied that there are several which are distinct. It is very improbable that a genus of Cystideans, ranging from the Chazy limestone to the Hudson River group, and spreading over so vast a geographical area as that which lies between Canada West and Bohemia, should have but one species. Still it is not easy to find many good specific characters to separate those in the collection at Montreal. The following appear to me to be distinct; but when the genus becomes better known, it may be necessary to make some other disposition of them :—

I. Pleurocystites squamosus, Billings.

Plate I. Figures 1*a*, 1*b*, 1*c*, 1*d*.

(*Canadian Journal*, vol. ii. p. 251, 1854; *Geol. Survey of Canada, Report*, 1856, p. 286.)

Description.—In this species the large plates on the dorsal side are smooth, or but slightly marked with obscure radiating and concentric ridges, and the opening on the anterior side is protected by an integument composed of a vast number of small, mostly hexagonal plates, each less than the fiftieth part of an inch in diameter near the border, and about the twentieth of an inch in the centre of the space. The rhombs are small and somewhat elliptical, the larger axes of the upper two being transverse to the length of the fossil; in a specimen with a body thirteen lines in length the left upper rhomb has a transverse axis of three lines and a vertical axis of two lines in length. The rhomb on the right is two lines long and one and a-half broad; the basal rhomb is about of the same size as the last mentioned; they are all slightly elevated above the general surface, and either flat or only a very little concave. The pores extend completely across the rhomb from one side to the other. The column is strongly annulated, and the projecting joints or rings striated vertically, so that when well preserved they have a nodulose appearance.

Explanation of Figures. Plate I.

Figs. 1*a* and 1*b*. Dorsal views of two specimens.

Fig. 1*c*. Ventral view of a specimen shewing the plated integument and strong borders formed by the folding over of the dorsal plates; the mouth is at *o*.

Fig. 1*d*. Ventral view of the upper part of the cup and arms of a specimen of this species, the remainder of which is completely buried in the stone; 1*e* is the same enlarged; at *a* is the small sub-apical aperture. It is represented too large in the figure.

Locality and Formation.—Trenton limestone, near the middle of the formation at Ottawa.

Collectors.—E. Billings, J. Richardson.

II. Pleurocystites robustus, Billings.

Plate I. Fig. 2*a*.

(*Canadian Journal*, vol. ii. p. 252, 1854; *Geol. Survey of Canada, Report*, 1856, p. 286.)

Description.—In this species the rhombs are obscurely elliptical, or rather in the shape of a spherical triangle; they have somewhat the appearance of a rhomboid, but then the angles are so much

rounded that an elliptical figure is approached, which owing to the slight curvature of the upper side, is also triangular. They very much resemble the rhombs of *P. squamosus*, but have a concave instead of a plane surface, as in that species; they are surrounded by an elevated rounded border. The surface of the plates upon the dorsal side is ornamented with fine rounded radiating striæ, which are always at right angles to the margin of the plates. In addition to the small striæ on some of the plates, an obscure ridge runs from each of the angles towards the centre of the plate.

This species only differs from *P. squamosus*, as far as can be ascertained from the few fragments collected, in the form of the rhombs and striation of the surface; it appears also to have been a larger and more vigorous species. It is very difficult to decide whether it be really distinct from the other or not.

Length of the upper left rhomb, three lines and a-half; breadth in the vertical direction, three lines; the right rhomb is somewhat smaller.

Explanation of Figure. Plate I.

Fig. 2*a*. Shews a fragment of the upper part of a specimen. From the position in which the artist viewed the specimen, the left rhomb in the figure appears too angular on the upper side.

Locality and Formation.—Trenton limestone, City of Ottawa.
Collector.—E. Billings.

III. Pleurocystites filitextus, Billings.

Plate II. Figs. 1*a*, 1*b*.

(*Canadian Journal*, vol. ii. p. 252, 1854; *Geol. Survey of Canada, Report*, 1856, p. 286.)

Description.—The pectinated rhombs of this species are of a very different shape from that of the same organs in *P. squamosus* and *P. robustus*. They have their greatest length in the vertical direction instead of the transverse, as in the other species. In the structure of the integument of the ventral side there is also a difference, which cannot but be of specific importance. The plates (see pl. ii. fig. 1*b*) are ten times the size, and consequently greatly less in number. The surface of the dorsal side of the specimen figured is marked by strong ridges radiating from the centre to the angles of the plates. Two fasicles of coarse rounded ridges, five in each, proceed from the centre of the large hexagonal plate of the second series on to the two central plates of the third series, crossing the sutures at right angles.

Similar ridges, but fewer in number, cross the sutures between the other plates at right angles. In some of the specimens there are pretty strong concentric lines interwoven with the others, and portions of the surface, especially where there is no striation, are roughened by the presence of small irregular tubercles. In other specimens the whole of the surface appears to have been striated at right angles to the sutures, and it is quite certain that in all the species of this genus there was more or less variation in the character of the striation.

Length of the upper left rhomb, five lines in a specimen fourteen lines long; of the right rhomb, three lines. The form of the basal rhomb has not yet been precisely ascertained, but appears to be of an elliptical shape, its greatest length lying in the direction of the suture upon which it is placed.

EXPLANATION OF FIGURES. Plate II.

Fig. 1*a* is a specimen which has the column and a portion of the arms firmly attached to a piece of limestone. The greater part of the body however is loose, and can be removed in one piece, giving a view of the ventral side. Fig. 1*b* is the ventral side, shewing the large plates of the integument, and obscurely the small aperture near the apex. The specimen is somewhat distorted by pressure, so that the true form of the rhombs cannot be made out. *o*, the mouth.

Locality and Formation.—Trenton limestone, City of Ottawa. In one locality the surface of a bed of limestone for several yards square was covered with the separated plates and joints of the columns of this species. The highly instructive and valuable specimen figured is the most perfect that has been found.

Collector.—E. Billings.

IV. PLEUROCYSTITES ELEGANS, Billings.

Plate II. Figs. 2*a*, 2*b*, 2*c*, 2*d*.

(*Geological Survey of Canada, Report*, 1856, p. 287.)

Description.—This species much resembles *P. filitextus*, but may be readily distinguished by the rhombs being shorter, and by the much stronger striation, in proportion to the size, over its whole surface. The rhombs have a more regular outline than those of *P. squamosus* or *P. robustus;* they are bounded by four nearly straight sides, instead of curved lines; the poriferous areas are however somewhat rounded at the upper angles, while the form of the border is such as to give to the whole organ a regularly rhomboidal aspect. The shape is best shewn in fig. 2*a*, and in the basal rhomb of 2*c;* by comparing

the latter with the portion of the basal rhomb of *P. filitextus*, represented in 1*a*, the difference will be at once detected; all the others are more or less distorted. In *P. filitextus* the left upper rhomb is a little more than one-third the length of the body, but in *P. elegans* it is a little more than one-fourth. The plates of the ventral side have not yet been seen.

EXPLANATION OF FIGURES. Plate II.

Figs. 2*a*, 2*b*, 2*c* and 2*d*? are dorsal views of this species. It is doubtful whether 2*d* should be referred to this species or to the thickly striated varieties of *P. filitextus*. The crushed condition of this, and indeed of all the specimens, renders it most difficult to decide when the species are so closely allied.

Locality and Formation.—Trenton limestone, City of Ottawa.

Collector.—E. Billings.

V. PLEUROCYSTITES EXORNATUS, Billings.

Description.—Rhombs sub-triangular, surrounded by a thin sharp border, which is a good deal elevated above the surface. The upper side of the rhomb is nearly straight, and the other two sides converge to a slightly rounded angle below. The outline of the rhombs of this species is like that of *P. robustus;* but, on the other hand, the poriferous area or portion has a flat surface, while in the other species it is concave. The plates of the ventral integument are about the size of those of *P. filitextus*, from which species it differs by the form of the rhombs; the size of the ventral plates also separates it from *P. squamosus.* The column is beautifully striated longitudinally.

Locality and Formation.—Lower part of the Trenton limestone, Montreal. Fragments resembling this species occur in the Chazy limestone near Montreal.

Collector.—E. Billings.

VI. PLEUROCYSTITES ANTICOSTIENSIS, Billings.

Plate I. Figure 3.

(*Geological Survey of Canada, Report*, 1856, p. 288.)

Description.—All that can be said about this species is that the rhombs are very long and narrow, and the large joints of the column so coarsely striated that they appear to be nodulose. Only a fragment, consisting of a portion of the column and the lower part of the body, has been collected; the specimen measures eleven lines

from the base of the body to the upper angle of the large dorsal hexagonal plate, and the right half of the left upper rhomb is in length five lines and in breadth one line. The plates appear to have been smooth, and in this respect principally does the species differ from *P. filitextus*, which is much ornamented with radiating striæ. This is the only species we have as yet from the Hudson River group.

EXPLANATION OF FIGURE. Plate I.

Figure 3. Dorsal view of an imperfect specimen of this species.

Locality and Formation.—Charleton Point, Island of Anticosti; Hudson River group.

Collector.—J. Richardson.

Genus GLYPTOCYSTITES, Billings.

(*Canadian Journal*, vol. ii. p. 215, 1854; *Geol. Survey of Canada, Report*, 1856, p. 280.)

Generic Characters.—Body, elongate, cylindrical; test composed of four series of plates, of which there are four in the basal, and five in each of the second, third and fourth series; three of the basal plates are pentagonal, the fourth hexagonal; the mouth, in the only species in which it has been seen, is situated in the lower half of the body, its lower side being formed of a notch in that plate of the second series which rests upon the hexagonal basal plate; it is without a valvular apparatus; the ambulacral orifice is in or near the centre of the summit, where it receives the five ambulacral grooves of the arms; near it is a small anal? pore; there are from ten to thirteen pectinated rhombs; the arms are recumbent, and upon the apex of the fossil the ambulacral grooves are beset with small marginal plates; the pinnulæ are articulated in two series; the column is short, and tapering to a point at the lower extremity.

The plates of the cup of this genus are somewhat remarkable for their form. In the hitherto known Crinoideæ and Cystideæ they are polygonal and bounded by straight sides; but all the species of this genus yet observed have some of them with re-entering angles. By referring to pl. iii. fig. 1*a*, it will be seen that the basal series of *G. multiporus* is very regular, and exactly like that of the genus *Echino-encrinites* (Volborth), represented in fig. 1*b*, the only difference being that the dorsal plate is so much extended upwards as to separate two of the plates of the second series. These two plates are notched on the upper side for the reception of the small hexagonal plate of the third series. Several of the other plates are

also variously notched. In the species *G. Logani*, *G. Forbesi*, and *G. gracilis*, many of the plates have re-entering angles, but in their arrangement in the walls of the cup they form regular series.

The pectinated rhombs also exhibit some peculiar new features. In no other genus have more than three been observed, and these, in all the genera except *Echino-encrinites*, are placed one at the base of the dorsal side and two in the upper half of the body, as in the genus *Pleurocystites*. The surface of *Glyptocystites* shews that three is not the constant number. It was also supposed to be essential to these organs that each should occupy two contiguous plates, about half of the rhomb being upon one and the other half upon the other. In *Glyptocystites* we have the new character of-half rhombs in all the four species. Generic name from *glyptos*, sculptured.

Glyptocystites at one time appeared to me to be so closely related to *Echino-encrinites*, that I had much doubt as to the propriety of retaining the name. After having examined a number of good specimens of the Russian genus, in the Museum of Practical Geology, London, I am satisfied that there is no generic affinity between them, except in the presence of the two rhombs in the dorsal side of the base. In no other respect is there any near relationship. That the number and arrangement of the plates are the same in both genera, is not a character sufficient to unite them; otherwise we should be obliged to make but one genus of *Pseudocrinites* (Pearce), *Apiocystites* (Forbes), *Prunocystites* (Forbes), *Echino-encrinites* (Volborth), *Lepadocrinites* (Conrad), and *Glyptocystites*. In all of these there are four series of plates, as follows: Four basal plates, and five in each of the second, third and fourth series. If we seek for other characters, we find that the Russian genus consists of several species, which, taken together, constitute a group having in its general aspect no resemblance whatever to that group formed by the four species of the American genus. The European species have short angular bodies covered with thick plates, the ventral side sometimes greatly projecting, and only three pectinated rhombs obscurely developed; while all the species of our genus have elongated sub-cylindrical bodies, nearly covered with rhombs, some of them of a large size.

VII. Glyptocystites multiporus, Billings.

Plate III.

(*Canadian Journal*, vol. ii. p. 215, 1854; *Geol. Survey of Canada, Report*, 1856, p. 281.)

Description.—One inch in length, five lines in diameter, cylindrical,

obscurely five-sided, rounded at the apex, abruptly truncated at the base; mouth large, oval, without valves, situated with its upper margin about the centre of the length of the body; ambulacral orifice small, situated in the centre of the apex, a small pore near it on the right hand side; arms five, four of them extending down the sides to the base, the fifth only two or three lines in length; thirteen pectinated rhombs; column short, tapering to a point, annulated by alternately wide and narrow joints, the former of which are striated on their projecting edges in the longitudinal direction.

In this species the basal and second series of plates are pretty regular, but the third series contains two plates, which are very small in proportion to the others, an irregularity compensated by a corresponding enlargement of two of the plates of the fourth series, which are of so great a size that they extend from the top of the body down to the second series, and thus fill up the blank in the third series formed by the deficiency in the size of the two small plates mentioned (see pl. iii. fig. 1*a*). The whole of the upper half of the test presents very little of order in its structure, in consequence of this disproportion in the size of the plates.

The distribution of the pectinated rhombs is as follows:—

On the anterior side there are two rhombs, a small one just below the mouth on the right side and a large one above, which extends from the mouth nearly to the apex (see pl. iii. fig. *d*).

On the right side there are two; a small one near the apex and a large one below it, but still nearly altogether in the upper half of the fossil. Both of these are a little oblique, the large one with its upper extremity leaning forward, and the small one leaning backward (see pl. iii. fig. *c*).

On the posterior or dorsal side there are four, two at the base, one-half of each being on the basal plate of this side, and the other half on the contiguous plate of the second series; a third very small rhomb is situated between the two small plates of the third series, and a fourth very large one is divided between the two large plates of the fourth series in the upper half of the fossil (see pl. iii. fig. F).

On the left side there are five, a large one next the mouth, and at its upper angle another, which extends across the sides, sloping a little downwards, with a third which rises nearly perpendicularly from the posterior angle of the second one; below this there is a half-rhomb, and above the large one first mentioned in this division a very small rhomb, only seen in perfect specimens (see pl. iii. fig. E).

There is very little difference in the form of the rhombs. They have each, except the three smallest, a smooth space in the centre, which is a little elevated above the poriferous surface, and the pores are elongated clefts which pass under the central smooth place, so that the pores of the one side are continuous with those upon the other. The thin partitions between the pores penetrate some distance into the interior of the fossil. Figures *g* and *k*, plate iii. are sections made through a specimen to shew this character. In nearly all the rhombs one side of the smooth central space has an elevated border.

The arms are five in number, four of them extending down the sides from the apex to the base; the fifth is a short arm, and reaches only two or three lines from the summit on the left side (see pl. iii. fig. E). They are composed of double series of joints alternating with each other, and so loosely attached to the surface that they can be easily removed with the point of a sharp knife. The ambulacral grooves extend the whole length of the arms, and have on each side a row of seven or eight pinnulæ, those upon one side alternating with those on the other. The two anterior arms unite a short distance above the large rhomb, which is situated over the mouth (see figs. *a* and *n*); their two ambulacral grooves then form but one, and cross the apex to the posterior side (see fig. *g*), where they divide and run down the posterior pair of arms. In crossing the summit the groove sends out a branch to the short arm, and, throughout their length, small branches to the pinnulæ.

The ambulacral orifice is very small, and situated in the bottom of the groove, a little on the anterior side of that point where the groove from the short arm enters the main apical furrow. This aperture is usually concealed by the small marginal plates of the ambulacra shewn in fig. *g*. Of these there is a row on each side of the groove, and when the top of the fossil is so perfect as to exhibit them well-preserved, they are always so firmly interlocked that they completely close the furrow. In this state they no doubt formed a securely protected covered way for the passage of the ambulacral vessels to the arms.

The minute aperture on the left side of the apex, near the ambulacral orifice, is a minute pore situated in the centre of a small rounded tubercle (see fig. *g*).

The pinnulæ are scarcely one-third of a line in diameter, and about half-an-inch in length. They are articulated in two series.

EXPLANATION OF FIGURES. Plate III.

Fig. 1*a*. The plates of the calyx spread out; the dotted lines which extend from the top to the bottom indicate the course of the arms.
Fig. 1*b*. Plates of the genus *Echino-encrinites* figured here for comparison.
Fig. *d*. Anterior view of a perfect specimen of *G. multiporus*.
Fig. E. The left side of the same specimen.
Fig. F. The dorsal or posterior side of another specimen.
Fig. *c*. The right side.
Fig. *g*. The apex enlarged.
Fig. *i*. The base.
Fig. *n*. A specimen with the column attached, anterior view.
Fig. L. One of the rhombs enlarged.
Figs. *g* & *k*. Sections shewing the depth to which the partitions of the rhombs entered.

Locality and Formation.—Trenton limestone, City of Ottawa, Montreal and Beauport. Only fragments have been found at the latter two places, and all the perfect specimens, about sixty, were collected from a piece of shale about two yards square and one or two inches in thickness. There is good reason to believe that they lived and died upon this spot. The shale was a layer between two beds of limestone, the lower of which was partly composed of the detached plates of this species. Imbedded in its surface were several perfect specimens among the fragments. The shale which covered it was full of individuals with their columns and delicate pinnulæ attached. It is quite clear that they could not have been at all drifted about the bottom after death, otherwise they would at least have lost their columns and pinnulæ. It is more probable that they formed a little colony, growing on this spot at a considerable depth, and in clear water, and that the shale consists of a deposit showered down upon them from a superficial current, literally burying them alive.

Collector.—E. Billings.

VIII. GLYPTOCYSTITES LOGANI, Billings.

Plate IV. Figs. 1*a–h*.

(*Geological Survey of Canada, Report*, 1856, p. 282.)

Description.—Length of large specimens one inch and a-fourth; diameter eight lines; cylindrical, obscurely five-sided, abruptly truncated at the summit; base slightly rounded; each plate ornamented with from three to seven exceedingly elevated, somewhat thin, sharp ridges, which radiate from the centre to the sides; spaces between the ridges smooth, or very minutely striated concentrically; calycinal

ambulacral grooves, to the angles of the truncated apex, bordered by marginal plates, as in *G. multiporus*, and furnished near their extremities each with several smaller free arms, or stout pinnulæ, articulated in two series; there are about twelve or fifteen pectinated rhombs, each with a smooth central area, which is not elevated above the surface of the pores, but is quite flat, a character which separates this species from the next.

Neither the mouth nor the ambulacral orifice has been observed, owing to the imperfection of the specimens.

The column is short, strongly annulated, and tapering to a point at its lower extremity. The small joints are pentagonal, and present a very remarkable character in the fact, that their angles form five spiral lines round the column throughout its length. The large joints which constitute the annulations of the column appear to be circular; but none of the specimens are sufficiently well-preserved to shew clearly that they are so.

The pinnulæ are furnished on their ventral sides with minute marginal plates, similar to those of *Pleurocystites*. This appears to be one of those species in which the body of the arm was never developed, but only the grooves and pinnulæ.

The detached plates of this magnificent species can be readily distinguished from those of any other crinoid or cystidean of the Trenton limestone by the peculiar star-like appearance produced by the very elevated, sharp, and thin radiating ridges with which their surfaces are ornamented. Although a number of the bodies, many of them with the column attached, have been collected, yet none of them shew clearly that side upon which the mouth is situated. The plates are more regularly alternating than in *G. multiporus*. This species cannot be identified with the *Echino-encrinites anatinaformis* figured by Professor Hall in plate xxix. vol. i. Palæontology of New York. By referring to that work it will be seen, that the triangular spaces upon the plates between the large radiating ridges are strongly striated at right angles to the sides of the plates (see the two figures, 4*d* and also 4*g*, in the plate cited). In our species these spaces are quite smooth, or only marked by faint lines, which are concentric, and therefore run in a direction at right angles to that of the striæ of the New York specimens. Professor Hall's figures do not exhibit any pectinated rhombs; and further, by figure 4*c* it is shewn that the base of *E. anatinaformis* is composed of two pentagonal and two quadrangular plates; ours has three pentagonal and one hexagonal basal plate.

Explanation of Figures. Plate IV.

Figs. 1*a* and 1*b* are dorsal views of two specimens.

Figs. 1*c*, 1*d* and 1*e* are enlarged views of the interiors of three rhombiferous plates, shewing that the pores penetrate through, and that each on the inside is surrounded by an exceedingly thin elevated border.

Fig. 1*f*. A portion of the ambulacral groove of the apex, and one of the pinnulæ enlarged.

Fig. 1*g*. A fragment with two of the pinnulæ.

Figs. 1*i* and 1*j*. Fragments of columns; the specimens are crushed, and do not clearly shew the spiral arrangement.

Locality and Formation.—Trenton limestone, Island of Montreal; plates in an excellent state of preservation are extremely abundant in certain localities of the formation.

Collectors.—Sir W. E. Logan, E. Billings.

I beg to dedicate this species to the discoverer.

VIII. Glyptocystites Logani *var.* gracilis, Billings.

Plate IV. Fig. 2.

Description.—This species or variety differs from the last in its greater proportional length and form of the rhombs and column. There is a deep angular furrow around the margin of each rhomb, and the central space, instead of being quite level, is much elevated. In the only specimen collected there is no unperforated area in the centre of the rhomb, as in *G. Logani* proper. The large joints of the column are close together, whereas in the other form they are separated by an interval equal to or greater than their thickness. On account of these differences, I have thought it proper to name this form as a variety of *G. Logani.*

Locality and Formation.—Trenton limestone, Montreal.

Collector.—Sir W. E. Logan.

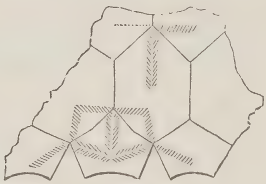
IX. Glyptocystites Forbesi, Billings.

Plate IV. Fig. 3.

(*Geological Survey of Canada, Report*, 1856, p. 283.)

Description.—The body of this species, judging from the fragments in the collection, is about two inches in length and three-fourths of an inch in diameter. The character of its surface is such, that detached plates may be distinguished at a glance from those of either of the two preceding species, being larger, thicker, and more

profusely ornamented with radiating ridges and striæ. Although there is an abundance of the comminuted remains in the Chazy limestone, yet only the base of the cup of one specimen has been found. Fortunately it is sufficiently well-preserved to shew that at least a great proportion of the numerous plates and columns with which it was associated belong to the same species. The specimen consists of four joints of the columns, two of the basal plates on the dorsal side, one large heptagonal plate of the second series, and portions of two others, one on each side of this latter. The following figure shows the disposition of the rhombs at the base of the dorsal side :—



At the base upon the dorsal side there are two perfect rhombs, one-half of each of which is on the central basal plate; the other two halves are upon the two plates of the second series, which rest upon the upper sloping sides of this basal plate. These two rhombs therefore correspond to the pair occupying the same position in *Echino-encrinites angulosus*, Volborth (see pl. iii. fig. 1*b*), and *G. multiporus*, pl. iii. fig. 1*a*. In addition however, we have in *G. Forbesi* two half-rhombs on two of the basal plates which do not occur in the other species; their positions are shewn in the above wood-cut.

The plates have two sets of surface ridges :—

1. From four to six large ridges, which radiate from the centre of each plate to the centre of each straight side of the plate. They are in general strongly elevated, with rounded or sharp edges and broad bases. In the angular spaces formed by the large ridges are smaller parallel ones, which form other included similar angular spaces (see plate iii. figs. 3*e* and 3*f*).

2. The whole surface of the plates is also covered with sharp concentric striæ, which are, on some of the plates, stronger between the ridges than upon them (see plate iv. figs. 3*e* and 3*f*). When the plates are worn, the large radiating ridges become rounded, and the concentric striæ are wholly obliterated.

The joints of the column attached to the fragment figured appear to be obscurely pentagonal; but in the same rock are many columns

which are round, and with the large joints ornamented with little pits or coarse striæ. It is not certain that these round columns belong to the same species.

EXPLANATION OF FIGURES. Plate IV.

Figs. 3*a* and 3*b*. Two views of the base of a specimen.
Figs. 3*c* and 3*d*. Imperfect plates, to shew the character of the rhombs. 3*d* has the remains of four rhombs ; 3*e* is the basal plate of the right side ; 3*f* the hexagonal basal plate of the anterior side ; 3*g* and 3*h* round columns, with the edges of the large joints pitted.

Locality and Formation.—Chazy limestone at Caughnawaga, and on the Island of Montreal.

Collectors.—Sir W. E. Logan, J. Richardson, E. Billings.

Genus COMAROCYSTITES, Billings.

(*Canadian Journal*, vol. ii. p. 269 ; *Geological Survey of Canada, Report*, 1856, p. 288.)

Generic Characters.—Body, ovate, the smaller extremity being the base; pelvis, small, of three plates, above which are from eight to eleven irregular rows of plates, mostly hexagonal ; mouth, near the summit, provided with a valvular apparatus ; arms, free, grooved, and composed of a single series of joints bearing pinnulæ ; ambulacral orifice in the apex between the arms ; column, round and smooth. The plates of the only species that has been collected present, in some conditions of preservation, a peculiar vescicular structure of their exterior surfaces, while sometimes they are solid and smooth. Generic name, *comaron*, a strawberry.

X. COMAROCYSTITES PUNCTATUS, Billings.

Plate V.

(*Canadian Journal*, vol. ii. p. 270 ; *Geological Survey of Canada, Report*, 1856, p. 288.)

Description.—The body of this species is of an oval or pyriform shape, and in large specimens about one inch and a-half in length. It is protected by plates which have a deep concavity, occupying nearly the whole of the area of each, the effect of which is to cover the surface of the fossil with large rounded pits, an aspect that serves to distinguish it at the first glance from any other known in the Lower Silurian rocks of Canada. In certain states of preservation the sutures are marked by minute thickly-set square or oblong rough punctuations, which do not however appear to penetrate through to the interior. In some specimens there is only one, and in others

two or three rows of these punctures upon each suture. The greater portion of the area of the plate is marked with deep fissure-like striæ at right angles to the suture, and with thin erect lamellæ or partitions between them. These are sometimes crossed by other lamellæ parallel with the edges of the plates, the effect of which is to produce a peculiarly rough surface. Sometimes none of these are visible, and the surfaces of the plates are then uniformly smooth and solid. These variations are the results both of weathering and structure. Portions of the centres of the plates of the two specimens figured (pl. v. figs. 1 and 2) have the external surface smooth, while the margins are rough.

The mouth is large, near the apex, and closed by a pyramid of five triangular valves.

The ambulacral orifice has not yet been distinctly observed, but there can be little doubt of its existence. The arms are four in number, and consist of an anterior pair situated directly over the mouth, and a posterior pair placed opposite, on the posterior side of the summit; a deep narrow groove crosses the apex, in a direction from the anterior to the posterior side; from one end it sends up two branches into the anterior pair of arms, and from the other end two into the posterior pair. The arrangement of the ambulacral furrows in this species is then precisely as in *Glyptocystites multiporus*, and no doubt an orifice will yet be found in the bottom of the groove, upon the summit between the two pairs of arms. The arms consist of a single series of joints, each about one line and a-half in length; the pinnulæ are nearly cylindrical, and divided by joints at lengths of about half a line. In the only specimen known with the arms attached (plate v. fig. 1) one side of the arm only can be seen, the other being imbedded in the rock. It shews that upon at least the side exposed there is one pinnula to each joint, but whether there is a row on the other side of the groove or not remains to be ascertained.

The column is round and smooth, formed of very thin joints, and does not, in a specimen with three inches preserved, exhibit any signs of tapering.

EXPLANATION OF FIGURES. Plate V.

Fig. 1. Anterior view of a large specimen, with one arm and the pinnulæ attached. *o*, the mouth; 1*a*, a plate of the same enlarged, to shew the peculiar striation; 1*b*, the valvular apparatus of the mouth enlarged.

Fig. 2. View of the left side of another specimen; 2*a*, a plate of same enlarged; 2*b*, outline of the summit, shewing the positions of the bases of the arms, and the ambulacral groove between them.

Locality and Formation.—Trenton limestone, City of Ottawa. Fragments are not very uncommon, but perfect specimens exceedingly rare.

Collectors.—E. Billings, J. Richardson, and others. The specimen fig. 2 was found by Captain W. S. Hunter of Ottawa, and fig. 1 by E. Billings.

Genus AMYGDALOCYSTITES, Billings.

(*Canadian Journal*, vol. ii. p. 270, 1854; *Geol. Survey of Canada, Report*, 1856, p. 288.)

Generic Characters.—Body, ovate; pelvis of three plates, above which are eight or more irregular rows of plates; the mouth is near the summit, closed by a valvular apparatus; arms, large, recumbent, composed of a double series of joints bearing a single row of pinnulæ; ambulacral orifice situated in the apex; ambulacral groove not in the centre of the upper surface of the arm, but on one side; column round; the plates are solid, or not poriferous. Generic name from *amygdale*, an almond.

Comarocystites differs from this genus by the possession of free arms and the porous character of its plates.

XI. AMYGDALOCYSTITES FLOREALIS, Billings.

Plate VI. Fig. 1*a*–1*e*.

(*Canadian Journal*, vol. ii. p. 270, 1854; *Geol. Survey of Canada, Report*, 1856, p. 289.)

Description.—Body ovate, rounded at the apex, tapering towards the base, about one inch and a-half in length. Each of the plates of this species has a low rounded tubercle in the centre, from which ridges radiate to the angles; these ridges are scarcely elevated above the surface where they leave the border of the tubercle in the centre, but increase in width and height as they depart from it; they are sharp-edged, and attain their greatest height at the angles of the plates. The arm crosses the summit, and extends nearly down to the base upon one side, and only two or three lines from the apex on the other; it is composed of a series of large joints, which are about one line in height and scarcely so much in width, and a second series of smaller pieces about one-half the height which are placed at the bottom of the larger, upon one side. The arm thus composed forms a projecting ridge up the posterior side of the body across the apex, and a short distance down the anterior side.

Each one of the large joints bears a pinnula, and the ambulacral groove is situated not on the top of the arm, but on one side. On the posterior side of the fossil the groove is on the left side of the arm. On the apex there appears to be an interruption, as if one of the joints were absent; the ambulacral orifice is no doubt situated at this point, but it has not been clearly made out in any of the specimens yet procured. From this supposed position of the ambulacral orifice proceeding forward the groove is on the right side of the arm, the mouth being on the left, as shewn in plate vi. fig. 1*a*, at *m*.

The column is round, smooth, and composed of thin joints.

In this interesting form we have an example of a Cystidean with a body composed of an indefinite number of plates, like the *Sphæronites*, and with the arms arranged exactly as they are in *Pseudocrinites*, a genus characterised by a few plates which are definite in number.

EXPLANATION OF FIGURES. Plate VI.

Fig. 1*a*. The left side of a specimen; *m*, the mouth. Fig. 1*b*. Right side of the same. 1*c*, posterior; and 1*d*, anterior views. The groove is not clearly shown in this specimen. 1*e*, one of the plates enlarged.

Locality and Formation.—Trenton limestone, City of Ottawa.
Collector.—E. Billings.

XII. AMYGDALOCYSTITES TENUISTRIATUS, Billings.

Plate VI. Figs. 2*a*–2*f*.

(*Canadian Journal*, vol. ii. p. 271, 1854; *Geol. Survey of Canada, Report*, 1856, p. 289.)

Description.—Body elongate, ovate; plates smooth in the centre; a low rounded ridge proceeds from the smooth space in the centre of each plate to each of the angles, where it meets the similar ridges which radiate from the centres of the adjoining plates; between these ridges the triangular spaces are finely but very distinctly striated at right angles to the sutures. The mouth is close to the arm on the left side, near the summit.

The specimen represented by figs. 2*a* and 2*b* is the one upon which I drew up the original description published in the Canadian Journal in 1854. It shews only fragments of the arm, and the surface of the plates is so different from that of *A. florealis*, that I then had no doubt of the distinctness of the two species. Last summer, however, I found at Belleville, Canada West, the other specimen, fig. 2*c*, which has much the form of *A. florealis*, and the

arm almost precisely the same, but the plates are striated like those of *A. tenuistriatus*. It seems to connect the two species, but until good clear specimens can be examined, it would be the better plan to retain the two names.

EXPLANATION OF FIGURES. Plate VI.

Figs. 2*a*, 2*b*. Right and left side of the Ottawa specimen; *m*, the mouth. 2*c*. Left side of specimen from Belleville, shewing a portion of the arm. 2*e*. The arm enlarged, shewing the ambulacral groove. 2*f*. View of the top of the arm, shewing the articulating cavities of the pinnulæ, and the branches of the ambulacral grooves leading to them. 2*d*. A plate enlarged, shewing the striæ.

Locality and Formation.—Trenton limestone: one specimen from the city of Ottawa and one from Belleville. The species appears to be excessively rare.

Collector.—E. Billings.

XIII. AMYGDALOCYSTITES RADIATUS, Billings.

Plate VI. Figs. 3*a*, 3*b*.

(*Canadian Journal*, vol. ii. p. 271, 1854; *Geol. Survey of Canada, Report*, 1856, p. 289.)

Description.—Body ovate; plates somewhat convex, and ornamented with strong ridges which radiate from the centres to the angles; mouth ambulacral orifice and arms, unknown; column round smooth composed of thin joints.

The spaces between the large radiating ridges are flat and covered with small tubercles, which disappear when the plates are a little worn.

Of this fine and very distinct species, enough has not yet been found to shew conclusively that it belongs to the present genus. The plates however are solid, or not poriferous, and the shape of the body and column is so much like the other species, in general aspect, that I have referred it to this genus for the present.

EXPLANATION OF FIGURES. Plate VI.

Fig. 3*a*. A specimen crushed flat. 3*b*. One of the plates enlarged. The specimen is worn, and does not shew the granular surface of the spaces between the radiating ridges.

Locality and Formation.—Trenton limestone, City of Ottawa.

Collector.—E. Billings.

Genus Malocystites, Billings.

Generic Characters.—Body ovate or globular, composed of an indefinite number of plates, usually about forty or fifty; mouth, almost apical; ambulacral orifice on one side, but in the upper half of the body; arms recumbent, in some species numerous; plates thick solid, not poriferous; column unknown. Generic name from *malum*, an apple.

This genus is composed of some species of Cystideans lately discovered in the Chazy limestone. They are usually globular, and covered with smooth plates, and in general form and aspect much resemble the *Echinosphærites* of Scandinavia and Russia, from all of which however they differ in the absence of pores in their plates.

The genus *Cryptocrinites* (Von Buch) is related to *Malocystites* so far as regards the absence of pores or pectinated rhombs, but differs in having the ambulacral orifice in the apex, the mouth being in the side, and appears to be composed of a definite number of plates, there being three in the basal series, five in the second series, and alternating with these, five others in the second series.

Malocystites differs from *Amygdalocystites* in being composed of a lesser number of plates, and in having the ambulacral orifice in the side, and the mouth nearly in the centre of the apex. The arms appear also not to be alike in the two genera, although none of the specimens are sufficiently well-preserved to shew the structure very distinctly.

XIV. Malocystites Murchisoni, Billings.

Plate VII. Figs. 1*a*—1*i*.

Description.—Body globular, or slightly ovate; plates varying from plane to convex, covered with small granular tubercles; arms usually eight, forming two fascicles of four in each, connected by a short groove, in the bottom of which is the ambulacral orifice; they are long, and wind around the body obliquely descending from the orifice nearly to the base; mouth nearly circular, without valves. In a specimen eleven lines long and ten lines in greatest breadth the ambulacral orifice is half a line broad, and the mouth one line and a half. The area of the mouth is therefore about nine times greater than that of the ambulacral orifice.

This species presents some variations in form and size. The greater number of the specimens are nearly globular, and about one inch in diameter. Fig. 1*e*, plate vii. represents an individual that is ovate, the length being fifteen lines and the breadth twelve lines. Fragments have been observed which must have belonged to specimens two inches in diameter. The plates are also sometimes exceedingly convex, the sutures being depressed. In specimens with smooth surfaces, or with the plates not convex, it is almost impossible to distinguish the sutures.

Dedicated to Sir Roderick I. Murchison, F R.S., G.S., &c. &c. Director-General of the Geological Survey of the United Kingdom of Great Britain and Ireland; author of "The Silurian System," etc.

Explanation of Figures. Plate VII.

Fig. 1*a*. Right side of a specimen, shewing the ambulacral orifice and the eight arms. 1*b*. The left side, shewing the position of the mouth, *m*. 1*c*. Vertical view of the ambulacral orifice. 1*d*, 1*e*, Left sides of two other specimens. 1*f*. Apex of 1*e*. 1*h*. Base of 1*d*, shewing the three basal plates. 1*i*. Portion of upper surface of an arm magnified.

Locality and Formation.—Chazy limestone, Caughnawaga and Island of Montreal. Fragments are exceedingly abundant; good specimens rather uncommon.

Collector.—E. Billings.

XV. Malocystites Barrandi, Billings.

Plate VII. Figs. 2*a*—2*c*.

Description.—In this species the body is nearly globular, and the plates smooth, or very minutely granulated with small tubercles. The mouth is five-sided, and situated almost exactly in the centre of the apex or diametrically opposite the point of the attachment of the column. The arms are two in number, and very short, each being not more than three or four lines in length. They are so disposed as to form two half-circles, with the inner curves facing in opposite directions. They are connected by the usual ambulacral groove, in the bottom of which is the orifice. There are eight joints in the arm preserved in the specimen fig. 2*b*, pl. vii. which is the posterior arm, or that most distant from the mouth. The specimen represented by fig. 2*c* has the anterior arm preserved, and it shews only four joints.

If a section be made passing through the ambulacral orifice, the mouth and base of a specimen of this species, it will exhibit the following arrangement of the orifices:—

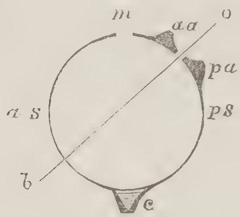


Fig. 1.

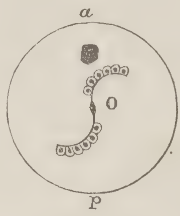


Fig. 2.

In the above fig. 1, *m* is the place of the mouth, *aa* the anterior arm, *o* the ambulacral orifice, *pa* the posterior arm, *c* the column, *as* the anterior, and *ps* the posterior side. Fig. 2 is a diagram of a specimen seen in the direction of the line *ob* of figure 1, shewing the arrangement of the arms in two half-circles, one of which is between the mouth and the ambulacral orifice, the other being on the opposite side.

The mouth of this species being five-sided, was probably provided with valves. It is one line in diameter, and is therefore more than four times the area of the ambulacral orifice, which has a length of less than half a line.

Some small specimens in the collection shew that when young this species was of an oval or pyriform shape.

Dedicated to M. J. Barrande of Prague, Bohemia, author of "Systême Silurien du centre de la Bohême," &c. &c.

Explanation of Figures. Plate VII.

Fig. 2*a*. View of the left side of a specimen; *a*, the arm. 2*b*. Posterior view of the same. 2*c*. Anterior view of another specimen. 2*d*. The arm of 2*a* magnified, shewing the short branches of the ambulacral furrow to the bases of the pinnulæ.

Locality and Formation. — Chazy limestone, near the city of Montreal.

Collectors.—E. Billings and J. McMullen.

Genus Palæocystites, Billings.

Generic Characters.—The body is oval or pyriform, composed of numerous plates, which are poriferous; the pores penetrate the

margins of the plates and extend towards the centre, but do not open out on the exterior surface. On the interior surface they open between the edges of the plates. Column, arms and orifices unknown. Generic name from *palaios*, ancient.

The most abundant species of this genus appears to be identical with that fossil of the Chazy limestone to which Professor Hall has given the name of *Actinocrinus tenuiradiatus.* (See Palæontology of New York, vol. i. p. 18, plate iv. figs. 8 and 9.) I have ascertained however that it is a Cystidean. No perfect specimens have been found, but several fragments, which I have collected, consisting each of about one-third of the body, shew that it is a genus allied to *Comarocystites*, *Sphæronites* and others of the many-plated group.

This genus appears to be closely related to *Amygdalocystites.*

XVI. Palæocystites tenuiradiatus, Hall sp.

(*Actinocrinus tenuiradiatus*, Hall. Pal. N. Y., vol. 1, p. 18, pl. iv, figs. 8 and 9.)

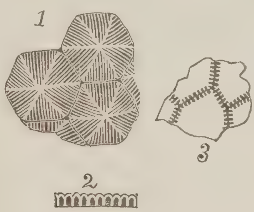


Fig. 1. View of exterior of several plates of *P. tenuiradiatus.*
Fig. 2. Edge of a plate, shewing the entrances of the pores.
Fig. 3. Inside of several plates, shewing the opening of the pores in the suture.

Description.—Large specimens are two inches or more in length and pyriform in shape, the upper part of the body being the largest. The plates are depressed conical, and when a little worn are all covered with deep fissure-like striæ, which are at right angles to the edges. These striæ cross from one plate to the next contiguous, so that one half is upon one plate and the other half upon another. At the suture in the bottom of each of those fissures is a small aperture that penetrates through, being partly excavated in the margins of each of the plates respectively. The effect of this mode of striation is to cover the whole surface of the fossil with small rhomboidal areas, each of which occupies portions of two plates. There are as many half-areas on each plate as the plate has sides. When the surface has not been worn the interesting fact may be clearly

seen, that all the striæ are covered by a thin external layer, which closed them completely over, so that there were no pore-mouths on the exterior. It therefore follows, that what appears to be ordinary striæ are in fact the channels of a peculiar set of pores which run beneath the surfaces of the plate, and communicate with the interior through orifices in the suture. Hence in a perfect plate, the margin on the inside is deeply notched, each notch being one-half of a pore-mouth. On the outside it is not notched. The pores do not open any where upon the surface of the plate, neither do they communicate with each other. When the plates are perfect, the surface is still striated; but the striæ correspond to, and are situated over, the partitions between the channels of the pores which constitute the striæ of the worn plates. The number of pores in the sutures depends upon the size of the plates. In a plate, with sides two lines in length, there are nine pores.

Geological Position and Locality.—Detached plates, common in the Chazy limestone at Caughnawaga and on the Island of Montreal. They also occur in the same formation near Hawkesbury, and at Chazy, in the State of New York.

Collectors.—Sir W. E. Logan, J. Richardson, E. Billings, R. Bell, and J. McMullen.

XVII. Palæocystites Dawsoni, Billings.

Description.—Of this species I have collected several fragments of the body, two of which are especially interesting, as they exhibit the exterior of some of the plates, and thus afford the means of shewing that they are generically related to the last species. The body is elongated pyriform, or rather fusiform, the lower part being the smaller extremity. The apex appears to be rounded. The plates are ornamented with strongly elevated rounded ridges, the number of which corresponds to the number of the sides; those with five sides having five ridges, and those with six or seven sides, six or seven ridges. Each ridge is continued from the centre of one plate straight across the suture to the centre of the next. There are no pore-mouths on the outside; but on the inside there is one for each ridge, situated on the suture, exactly as in the last species. The pores in this species do not penetrate so far towards the centre as in the last.

The largest specimen collected, is a fragment of the lower half, and indicates that the length of the body was about one inch, its

greatest diameter being half-an-inch. Another specimen, nearly perfect, was about half-an-inch in length, and one-fourth in breadth; it was unfortunately destroyed in getting it out of the rock. A fragment of the top however was preserved, and although half imbedded in the matrix, shews clearly enough that it has a rounded summit.

Dedicated to Dr. J. W. Dawson, LL.D., author of "Acadian Geology," &c. &c. Principal of the University of McGill College, Montreal.

Geological Position and Locality.—Chazy limestone, near the first mile-post, St. Lawrence Street, Montreal.

Collector.—E. Billings.

XVIII. Palæocystites Chapmani, Billings.

Description.—The few plates of this species that have been collected exhibit the peculiar character of the genus in a most interesting and satisfactory manner. Without being acquainted with the structure of the plates, the observer would almost unhesitatingly refer them to two very distinct species, so great is the change in their appearance produced by the wearing away of the external surface. The perfect plates resemble those of *P. Dawsoni*, inasmuch as the number of radiating ridges is the same as the number of sides. The ridges are however of a different form. In *P. Dawsoni* they are narrow at the base, and the space between them is flat; but in *P. Chapmani* they are broad at the base, or roof-shaped, the base of each spreading out to a breadth equal to the length of that side of the plate to which it extends. A perfect plate of this species, for instance one of six sides, may therefore be described as presenting six furrows radiating from the centre to the six angles, these furrows gradually increasing in depth and width as they recede from the centre of the plate. Or it may be characterised as exhibiting six roof-shaped ridges radiating from the centre to the sides, and increasing in height and width at the base as they approach the side.

When however the external surface is worn away, the plates assume a very different appearance. They then become covered with deep fissure-like striæ, like those of *P. tenuiradiatus*, to which they bear so close a resemblance, that to the unpractised eye, they appear to be the same. They can always however be distinguished by this character. The ridges or partitions between the fissures, which terminate at the centres of the sides of the plates, are the

highest, those at the angles being the lowest; but in *P. tenuiradiatus* it is the very reverse: the angles of the plate are more elevated than the centres of the sides.

I dedicate this species to E. C. Chapman, Esq., Professor of geology and mineralogy, in University College, Toronto.

Locality and Formation.—Lot 26, Front Concession of Clarence, Chazy.

Collector.—J. Richardson.

XIX. Ateleocystites Huxleyi, Billings.

Description.—The extraordinary little fossil, for which the above name is proposed, is no doubt a Cystidean; but of a group somewhat widely separated from the ordinary types. There are several specimens in the collection, but they all are half imbedded in stone, and with one exception exhibit only the dorsal side. The form is subquadrate, rounded at the apex and nearly straight at the base. The dorsal side appears to have been quite flat when perfect, as the plates which constitute the edges are bent forward towards the ventral aspect at more than a right angle, so that the sides instead of being rounded presented a rather sharp edge. The ventral side was probably convex.

The plates of the dorsal side are arranged in four series. The basal series consists of four oblong plates, each of which is about twice as high as wide. These four constitute rather less than the lower half of the body.

In the second series there are three plates, the central one being broader than either of the other two; it rests upon the upper edges of the two plates which form the central pair of the basal series, and is about equal to them in width. The right side of this plate is longer than the left, owing to the truncation of the upper left hand angle. These three sides occupy a little more than one-fourth of the length of the dorsal side.

The third series consists of an irregular row of four or five small plates. There are two at the sides, and apparently three others resting on the large central plate of the second series. Of these however only two are distinctly visible, one in the centre and the other on the left sloping upper side of the plate below.

The fourth series is composed of a row of three or four small plates, forming the margin of the cup on the dorsal side. Above these and imbedded in the matrix are several small points which are suggestive of the marginal ambulacral ossicula of the ordinary Cystideæ.

One specimen shews a portion of the ventral side, consisting of numerous small plates, thus resembling the genus *Pleurocystites.*

The two large side-plates at the base are obscurely striated transversely. The body is one-third longer than wide. The plates are thin. The length of the largest specimen a little more than half-an-inch; width about four lines. All the characters that can be collected from the specimens are comprised in the above description. They are sufficient to shew that this is a distinct genus, and I propose for it the name of *Atelcocystites* from the Greek *ateles*, " defective or incomplete."

Professor Hall has kindly furnished me with some of the printed sheets of his forthcoming Vol. 3 of the Palæontology of New York, in which he has described a new genus *Anomalocystites*, from the Lower Helderberg series. The materials in my possession are not sufficient to enable me to refer the above to the New York genus.

The genera of Cystideæ have not usually so great a vertical range as that between the base of the Trenton and the top of the Upper Silurian. Should it be ascertained hereafter that the two genera are identical, this species must be referred to *Anomalocystites*, which has the precedence.

Another form belonging to this group has been discovered in the Upper Silurian in England.

Fig. 4.

The above wood-cut, fig. 4, represents the structure of the dorsal side as nearly as can be made out from the specimens in the collection.

The species is dedicated to T. A. Huxley, Esq., F.R.S., of the Geological Survey of the United Kingdom.

Locality and Formation.—Trenton limestone, farm of Mrs. Brigham, Township of Hull, near Ottawa.

Collector.—E. Billings.

In addition to the nineteen species of Cystideans described in the foregoing pages, there are fragments of two others, which are too imperfect to indicate the genus; but still sufficiently well preserved

to shew that they do not belong to any known species. One of them appears to be a *Glyptocystites*, and the other will I think yet turn out to be a small Cystidean of a new genus, with a nearly globular body, and three or four pectinated rhombs. I have seen them only in the Trenton limestone at Ottawa.

On the ASTERIADÆ *of the Lower Silurian Rocks of Canada.* By E. BILLINGS, Esq., F. G. S.

The following species of Star-fishes were described in the Report of the Geological Survey published in 1857, page 290 *et seq.*, with the following introduction:—

"The species of Star-fishes in the collection appear to be referrable to the genera proposed by Mr. Salter at the meeting of the British Association, in August last. I have seen no other description of these genera than that given in Silliman's Journal of November, 1856, which is as follows:

"PALÆASTER.—Without disc, avenues deep.

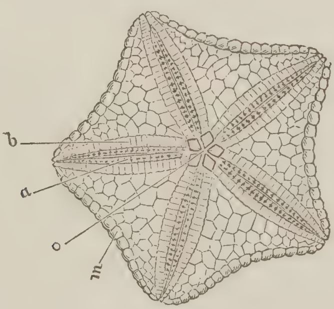
"PALÆASTERINA.—Pentagonal, disc moderate.

"PALÆOCOMA.—No disc, avenues very shallow.

"It is probable that our species, when opportunity can be had for a direct comparison with British specimens, wili be found congeneric."

Since then Mr. Salter has published full details of the above and some other genera,* and I have also examined some of the species described by him and Prof. Forbes.

* On some New Palæozoic Star-fishes. By J. W. Salter, Esq., F. G. S. Annals and Magazine of Natural History, November, 1857.



The above diagram is given to explain the sense in which the following terms are used in this memoir:

a. Ambulacral ossicles,—the small plates in the bottom of the ambulacral furrows, between which the pores for the passage of the suctorial feet pass.

b. Adambulacral plates,—the rows of plates which border the ambulacral grooves.

m. Marginal plates,—the row of plates round the margin of some of the species.

o. Oral plates,—situated at the angle of the mouth. In many species these consist of the ten terminal adambulacral plates.

Disc-plates,—I propose to call all the plates of the body which cannot be comprised in any of the above four classes, disc-plates.

After much consideration, I have resolved to adopt the following arrangement for the Canadian species.

Genus PALASTERINA, McCoy.*

(*As defined by Mr. Salter*, 1857.)

Generic Characters.—"Pentagonal, depressed; the arms a little produced, with three or five principal rows of tubercles above, combined with a plated disk which fills up the angles; ambulacra rather shallow, of sub-quadrate or slightly transverse ossicles, bordered by a single row of squarish large plates, the lowest of which (*ad-oral* adambulacral plates, Huxley †) are large and triangular, leaving combs of spines."

The following species having been already placed in the above genus, I am unwilling to create a new one for them until more is known as to what constitutes a generic character among the Star-fishes. Our specimens do not shew any spines, but perhaps they have not been preserved; and even could it be shown that *P. stellata* was without these appendages, it would still remain to be settled whether this difference is or is not of generic importance.

I. PALASTERINA STELLATA, Billings.

Plate IX. Fig. 1*a*, 15.

(*P. stellata, Geological Survey of Canada, Report*, 1856, p. 290.)

Description.—Pentagonal; disc about one half of the whole diameter; ambulacral grooves narrow and deep, bordered on each side by a row of small nearly square adambulacral plates; a second row consisting of disc plates extends nearly to the end of each ray, the remainder of the disc covered with smaller plates. All of these plates are solid and closely fitted together; the disc-plates in the angles in contact with the oral plates are much larger than any of the others.

In the only specimen in the collection the length of the rays measured along the ambulacral grooves is three lines; number of adambulacral plates on each side of the grooves sixteen; the rays diminish somewhat rapidly in size, and terminate in a rounded point; diameter of the disc four lines. The plates are all a little worn, so that the character of their surfaces cannot be observed; they were probably nearly smooth.

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* Suggested by Prof. McCoy, who did not however define the genus. British Palæozoic Fossils, p. 59, 1851.

† Angle-ossicula (Forbes), oral plates of this memoir.

EXPLANATION OF FIGURES.

Fig. 1*a*. The specimen natural size.
1*b*. The same enlarged.

Locality and Formation.—City of Ottawa. Trenton limestone.
Collector.—E. Billings.

II. PALASTERINA RUGOSA, Billings.

Plate IX. Fig. 2*a*, 2*b*, 2*c*.

(*Geological Survey of Canada, Report*, 1856, p. 291.)

Description.—Two inches in diameter; rays five, acute at their apices and rapidly enlarging to a breadth of four lines at the disc, which is eight lines in width. The specimen shews the upper side of the fossil only; some of the plates are absent from the centre of the disc, but those which remain are very prominent in their centres, and roughly ornamented with four or five deep crenulations or furrows from near the centre to the edges, producing a star-like appearance resembling a half-worn plate of *Glyptocrinus decadactylus*; their diameter is from one to two lines.

The rays are composed (at least the backs and sides of them,) of four rows of plates, which are so very prominent that they appear to be almost globular, and even pointed in their centres; the central rows are the smallest; the first four plates of the outer row occupy three lines in length, and of the inner rows nearly as many. Towards the point of the arm all diminish rapidly in size.

Beneath the outer rows two others can be seen, which are probably the outer marginal plates of the under side, corresponding to those of *P. rigidus*.

EXPLANATION OF FIGURES. Plate IX.

Fig. 2*a*. Dorsal view of a specimen. 2*b*. Fragment of another individual. 2*c*. One of the plates of 2*a* enlarged.

Locality and Formation.—Charleton Point, Anticosti. Hudson River Group.

Collector.—J. Richardson.

Genus STENASTER, Billings.

Generic Characters.—No disc; rays linear, lanceolate or petaloid; grooves bordered by solid oblong or square adambulacral plates; oral plates triangular and ten in number; two rows of ambulacral

pores. Dorsal side of disc and rays covered with small plates, which appear to be tubercular and not closely fitted together. The generic name is from the Greek *stenos*, narrow, in allusion to the contracted body.

As it has been suggested that the two species hereinafter described should be referred to *Palæaster*, I give the following figure of that genus in order to show the difference.

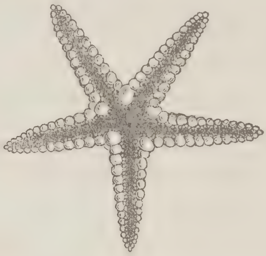

Fig. 1, *Palæaster Niagarensis*, Hall.

Upon examining the above figure, it will be seen that there is a great difference between *Stenaster* and *Palæaster*, for the following reasons:

1. If the large plates which border the groves in *Palæaster* be adambulacral, then there are only five oral plates, whereas in *Stenaster* there are ten.

2. But if they be not adambulacral but marginal plates, then *Palæaster* must have both marginal and adambulacral, while *Stenaster* has only the latter.

III. Stenaster Salteri, Billings.

Plate X. Fig. 1*a*, 1*b*.

Description.—This species has rather short broad rays, which are narrower where they are attached to the very contracted body than they are at about the centre of their length. In consequence of this form, the sides of the rays are not parallel, but a little curved outwards. As however only two specimens have been collected, and both appear to be a little flattened by vertical pressure, it may be that this leaf-like shape of the rays is accidental, and that in perfect specimens they taper uniformly from the body outwards. The adambulacral plates are oblong, and the sutures between them are nearly at right angles to the ambulacral grooves; those next the body are a

little sloping outwards. Their length is about twice their breadth, and they are so disposed that the greater dimension is transverse or at right angles to the groove; the extremities which lie next to the grooves are angular, and some of them appear to have the contiguous pores partly excavated in them. The oral plates are acutely triangular, the sharpest angle being towards the mouth. The plates are smooth. The ambulacral pores are very large, and the ossicles are much contracted in the middle and greatly expanded along the median line of the bottom of the groove.

The most perfect specimen is one inch in diameter measured between the tips of the rays; diameter of disc three lines; width of ray at mid-length two lines and a half.

Dedicated to J. W. Salter, Esq., Palæontologist of the Geological Survey of the United Kingdom.

Explanation of Figures. Plate X.

Figure 1*a*.—Ventral view of a specimen collected at Belleville.
1*b*.—The same enlarged.

Locality and Formation.—Belleville, Canada West. Trenton limestone.

Collector.—E. Billings.

IV. Stenaster pulchellus, Billings.

Plate X. Fig. 2.

(*Palæaster pulchella*, *Geological Survey of Canada*, 1856, p. 292.)

Description.—Rays long, slender and sub-cylindrical; adambulacral plates transversely oblong; grooves narrow; dorsal plates small and tubular. Diameter of the only specimen in the collection two inches and one-fourth measured between the tips of the rays; rays one inch in length, and two lines and a-half in width at the base; disc three lines and a-half in diameter.

Explanation of Figure. Plate X.

Fgure 2.—Ventral view of the only specimen collected.

Locality and Formation.—Ottawa. Trenton limestone.
Collector.—E. Billings.

Genus Petraster, Billings.

Generic Characters.—This genus has both marginal and adambulacral plates, with a few disc-plates on the ventral side. The general

form is deeply stellate, and the rays long and uniformly tapering. A single specimen has been collected, and as it shews the under side only, the characters of the dorsal surface cannot be given. The structure of the mouth is also unknown. Generic name from *petra*, a stone.

It differs from *Palasterina* by the presence of large marginal plates outside of the disc-plates, and still more from *Stenaster*, which has neither disc nor marginal plates. It is allied to *Astropecten*.

V. Petraster rigidus, Billings.

Plate X. Fig. 3.

(*Palasterina rigidus, Geological Survey of Canada, Report*, 1856, page 291.)

Description.—This species has much the aspect of an *Astropecten*; the disc is one-fourth the whole diameter, the rays rather slender and uniformly tapering; the angles between the bases of the rays rounded. The plates, which appear to be adambulacral, are quadrate and a little convex; the marginal plates oblong, and also convex; the disc-plates consist of three at each angle, and a single row on each side of the ray, but extending only one-third or one-half of the length of the ray; they all lie between the marginal and adambulacral plates.

The specimen figured was about two inches in diameter when perfect; width of disc half-an-inch, and of rays at the base about three lines.

Explanation of Figure. Plate IX.

Fig. 3*a*.—Ventral view of an imperfect specimen.

Fig. 3*a* appears to be the dorsal side of an individual of this species with the plates along the centre of the rays removed.

Locality and Formation.—Trenton limestone, Ottawa.

Collector.—J. Richardson.

Genus Tæniaster, Billings.

Generic Characters.—Body deeply stellate; no disc or marginal plates; rays long, slender, flexible, and covered with small spines; two rows of large ambulacral pores; adambulacral plates elongated and sloping outwards so that they partly overlap each other; adambulacral ossicles contracted in the middle, dilated at each end. Generic name from *tainia*, a riband.

This genus differs from *Protaster* as described by Mr. Salter in the Annals and Magazine of Natural History, November 1857, in the following particulars:—

1. *Protaster* has a well-developed disc.

2. It has also the pores outside of the ambulacral ossicles. See Mr. Salter's fig. 4*c*, in the article above cited.

3. The same figure shows that the oral plates of *P. Miltoni* are formed of two of the ambulacral ossicles, instead of two of the adambulacral plates.

These differences are too great to admit of our species being at all, unless very remotely, allied to *Protaster*.

VI. Tæniaster spinosus, Billings.

Plate X. Fig. 3*a*, 3*b*, 3*c*, 3*d*.

(*Palæocoma spinosa, Geological Survey of Canada, Report*, 1856, page 292.)

Description.—The specimens collected are about seven lines in diameter; the rays linear-lanceolate, one line in width at the base, and covered at the sides with numerous small spines.

In the view of the enlarged specimen (pl. x. 3*b*), the ambulacral ossicles appear in some places to alternate with each other, but this is owing to a distortion. Those on one side of the furrow are opposite those upon the other. The adambulacral plates are elongated, and so placed that the outer extremity of the one lies upon the inner extremity to the next. The rays are flexible.

Explanation of Figures. Plate X.

Figure 3*a*.—Ventral view of a small specimen.
3*b*.—The same enlarged.
3*c*.—Another specimen, with the rays bent upwards.
3*d*.—The same enlarged.

Locality and Formation.—Falls of Montmorency, Trenton limestone.
Collector.—E. Billings.

VII. Tæniaster cylindricus, Billings.

Plate X. Figs. 4*a*, 4*b*.

(*Palæocoma cylindrica, Geological Survey of Canada, Report*, 1856, page 292.)

Description.—About an inch and a half in diameter or a little more; rays sub-cylindrical, regularly rounded on the upper side, flattened on the lower, covered above with spines; about a line in width at the base, and tapering to an acute point.

This species is larger and more robust than the former. Both appear to be somewhat common, and the specimens are often found with their rays variously curved, showing that they were extremely flexible.

EXPLANATION OF FIGURES. Plate X.

Figure 4*a*.—Dorsal view of a specimen.
4*b*.—Ventral view of a different specimen.

Locality and Formation.—City of Ottawa. Trenton limestone.
Collector.—E. Billings.

Genus EDRIOASTER, Billings.

(Genus *Cyclaster, Geological Survey of Canada, Report*, 1856, page 292.)

Generic Characters.—Body sessile, circular, discoid, covered with numerous irregularly polygonal plates; mouth large, sub-pentagonal; five ambulacral grooves, each composed of two series of oblong ossicles; four rows of ambulacral pores to each groove. The mouth is formed of five oral and apparently five internal ossicles. The sutures between the ambulacral ossicles, in certain conditions of preservation, are enlarged so that the pores on each side are connected, and thus there appear to be two instead of four. Hence in the first description I gave of this species it was described as having two rows. Since then more perfect specimens have been procured, and I am enabled to correct this misconception. Generic name from *edriao*, to seat, in allusion to the sessile condition of the species.

In my report for 1856 this genus is called *Cyclaster;* but I find that this name had been a short time previously given to a genus of sea-urchins by M. Cotteau, and it is therefore necessary now to provide a new one. (See *Catalogue des Echinides Fossiles des Pyrénnées.* Par MM. Leymerie et Cotteau. Bulletin de la Société Géologique de France, 18 Fevrier à 17 Mars 1856.) This number of the Bulletin was published in March 1857, but my Report was not issued until the autumn following.

VIII. EDRIOASTER BIGSBYI, Billings.

(*Cyclaster Bigsbyi, Geological Survey of Canada, Report*, 1856, page 293.)

Description.—The body of this species is circular, about one inch and a half across, and half an inch in height in the centre. It is covered with numerous small plates of various sizes, and, except in the ambulacral areas, disposed without order. The mouth, situated

in the centre of the upper side, is about two lines in diameter, and apparently five-sided. The other aperture between the rays consists of a space covered with plates much smaller than the average size; these form a small elevation, which is imperfect in all the specimens I have seen, but enough remains to render it almost certain that there was an aperture of some kind in this place.

The ambulacral areas are five in number, radiating from the mouth, precisely like those of a common star-fish, and composed of two series of oblong plates which alternate with each other in the centre of the furrow. There are about ten of these plates to five lines in length, on each side of the ambulacrum. The pores pass between the plates, two being situated between each two. The ambulacra are three lines wide at the mouth, and about an inch and a half in length in full-grown specimens. As they recede from the centre they curve round towards the right in some specimens, and towards the left in others.

The mouth appears to be composed of ten plates; five of these are at the ends of the ambulacra, and the other five placed in the angles between the ambulacra. In some of the specimens the plates are all smooth, in others covered with small tubercles.

All the specimens that I have collected were seated upon the rock with the mouth upwards, and apparently somewhat flattened by pressure. It is probable that when perfect they were more globular than they are present. One specimen is detached, and shows that the plates covered the whole of the under surface, except a small space in the centre which appears to be without plates; perhaps this was the point of attachment; I see no evidence of a column.

Dedicated to Dr. Bigsby, one of the most able of the first explorers of the geology of this country.

I regret, that, in consequence of mistaking the meaning of Prof. E. Forbes' remarks on the genus *Agelacrinites* in his memoir on the British Cystideæ, I supposed this to be the specimen discovered by Dr. Bigsby, and accordingly gave it his name. Since then I have seen Dr. Bigsby's specimen, and find it to be *A. Dicksoni*. It is too late now to change the names.

Explanation of Figures. Plate VIII.

Figure 1.—Upper side of a specimen partly embedded in stone.

1*a*.—A polished section through the mouth and two of the grooves, showing that the pores penetrate through.

2.—Fragment of a crushed specimen, showing two of the rays.

2*a*.—A portion of fig. 2 enlarged to show the pores.

Locality and Formation.—City of Ottawa. Trenton limestone.

Collector.—E. Billings.

Agelacrinites Dicksoni, Billings.

Plate VIII. Figs. 3, 3*a*, 4, 4*a*.

(*A. Dicksoni*, *Geological Survey of Canada, Report*, 1856, page 294.)

Description.—The diameter of this species is from three quarters of an inch to an inch and a half; the rays are five in number, and constructed upon a plan somewhat different from that of *E. Bigsbyi*, being bounded by two rows of small plates, which rise from the surface and arch over the grooves. The upper ends of the plates on one side meet those of the opposite side, in a line along the centre of the ray, thus forming for each ray a sort of covered way. The spaces between the rays are paved with numerous flat sub-imbricating plates. The specimens do not show the central aperture distinctly, but between two of the rays there is an orifice which appears to have been surrounded by small plates. The width of the rays at their bases is from one to two lines, according to the size of the individual, and they taper uniformly to their extremities. In all the specimens I have seen, the rays curve round to the right hand, if we suppose that the side with the aperture is posterior. The marginal plates of the rays do not appear to alternate regularly, as in some of the figured species of this genus.

There are two rows of small circular indentations on each side of the rays, corresponding in their position to the ambulacral pores of *E. Bigsbyi*, only that in the latter they are in the bottom of the grooves. It cannot be ascertained whether they penetrate through between the marginal plates or not.

I have dedicated this species to Andrew Dickson, Esquire, of Kingston, C. W., one of the best workers in the field of Canadian geology.

The first specimen was discovered by Dr. Bigsby at the Chaudière Falls, at Ottawa, in 1822.

Explanation of Figures. Plate VIII.

Figure 4.—The original specimen discovered by Dr. Bigsby, and now in the Museum of Practical Geology, Jermyn Street, London.

4*a*.—The same enlarged.

3.—View of a different specimen, in the collection of the Geological Survey of Canada.

3*a*.—The same enlarged.

Locality and Formation.—City of Ottawa. Trenton limestone.

Collectors.—Dr. Bigsby, E. Billings.

I have placed *E. Bigsbyi* in the order Asteriadæ, because its structure appears to me to be more like that of the Star-fishes than that of the Cystideæ. None of the Cystideæ have ambulacra whose pores penetrate through the covering of the body, and therefore all such genera as *Edrioaster*, *Agelacrinites* and *Hemicystites*, belong to a very different division of the Echinodermata. When we know more of their structure it is probable that they will be arranged as a sub-order, for which the name *Edrioasteridæ* would be appropriate, as it would suggest their sessile condition on the one hand, and on the other their affinity to the Asteriadæ.

On Cyclocystoides, *a new genus of Echinodermata from the Lower and Middle Silurian Rocks.* By J. W. Salter, Esq., of the Geological Survey of Great Britain; and E. Billings, Esq., of the Canadian Geological Survey.

Under this name we wish to describe a form which has come under the notice of each of us—in the one case in a series of instructive specimens shewing the structure of the different parts from the Trenton limestone rocks of Canada; and in the other, a specimen shewing the entire form and general surface, which has been long known in the Llandovery Rocks or May-Hill Sandstone of England.

The affinities of the fossil may perhaps be better discussed when the structure of the two species with which we are acquainted has been described.

Genus Cyclocystoides, Billings and Salter.

Generic Characters.—Discoid, surfaces formed of an integument composed of numerous small granular plates, which appear to be radiately arranged; margin entirely surrounded by thick subquadrate plates, each of which presents upon its outer half two deep obtusely oval excavations. These, in perfect specimens, are covered over by minute polygonal plates, thus forming a tubular channel around the whole animal. This channel appears to have been connected with the interior by small pores penetrating through the marginal plates, there being one pore leading from each of the excavations. The margin or (perhaps) disc was also connected with a long tube, like the proboscis of some of the Crinoids, formed of many small polygonal plates.

I. Cyclocystoides Halli, Billings.

Description.—Flat, circular, from one to two inches in diameter; about thirty-six marginal plates, the unexcavated inner portions of which are subquadrate, convex, and slightly granular upon their

surfaces. The two marginal excavations of each plate are separated by a thin wall-like partition, and bordered at the sides and outer edge of the plate by a sharp rim. It thus follows that the channel around the margin of the animal was divided into twice as many compartments as there are marginal plates. The integument of the upper side, supposed to be the side on which the marginal plates are excavated, is connected to the inner edge of those plates, and does not extend over them; its surface is roughened by small tubercles. The integuments of the under side appears to extend under the marginal plates, and connect with the small plates which cover the excavations above.

Fig. 6 represents the remains of a specimen which was perfect, but imbedded in the rock to such an extent that only eight or nine of the marginal plates and a small portion of the integument of the upper side were visible. It was silicified, but not to such an extent as to resist completely the action of hydrochloric acid. It shewed clearly that the integument was attached to the inner edges of the marginal plates.

The following description of the figures contains all that can be be said further about these specimens:—

The specimens, four in number, collected by Sir William E. Logan, shew:—

1. In fig. 1, an impression of a nearly complete disk, more than an inch broad, with all the marginal ossicles complete. They form very nearly a circle, deficient only at one point, *a*, which may be only accident, or possibly as both the outer rim and inner series of ossicles are deficient at this point, it may indicate the position of a stem or attachment. At one other point, *b*, the margin is broken, but the inner row of ossicles appears to be continuous, so that if there be not an attachment at *a*—and no trace of any appendage exists—the animal was most probably free.

2. Fig. 2 shews the marginal plates, and in a good state of preservation, of more than three-fourths of the ring. There are twenty-six of these, and their form is rudely sub-quadrate, rounded on the inner margin, truncate and bilobed on the outer; each is divided into two conspicuous halves, of which the inner is convex, granuloso-tuberculate, and with close, parallel, vertical striæ on their sides (fig. 3*b*); the outer half, on the contrary, is deeply excavate, smooth, divided by a radiating ridge into two shovel-shaped portions, which at their inner base are each deepened into a circular pit, with a tubercle in it (as seen more plainly in the cast, fig. 6 and *a*). The outer free

edge, $3d$, is furnished with one, two, or more transverse plates, which also appear granular, supporting other smaller ones which appear to fill up all the space over the excavations, and to form a sort of polygonally plated tube. This tube is nearly complete at *a*, fig. 1, and from near this point a similar but truly cylindrical tube extends out beyond the ring of ossicles, and is seen at *b* complete, and at *c* with its upper surface broken away, forming a continuous tube fully three-quarters of an inch beyond the disk, and apparently not terminated even then; $2d^*$ shews it magnified.†

3. Fig. 5 shews a still more complete development of this marginal plating, and the difference in size of the basal plates (see fig. 5* and the marginal ones, *b*) is such as to suggest the idea of a distinct species. It is perhaps only a younger specimen, considerably abraded, but may however receive provisionally the name of *C. depressus*. The specimen 5 shews a considerable portion of the loosely-arranged and flattened ossicles of the disk, which are not closely plated, but leave large interstices between them. This structure is better seen in the small fragment of the central disk of figure 2 (magnified in figure 4), in which the granular surface of the plates, and their irregular arrangement with interstices, is very distinct.

Figs. 8 and 9 shew still more clearly the radiated structure of the upper surface in another species.

Fig. 6 is the opposite or under-side (at least the flatter and less ornamented side), and may be presumed to be *C. Halli*. The great ossicles here are marginal, and have no plated integument stretching out beyond them, the outer edge, $6b$, corresponding to the edge, $3d$, on the opposite face.

The silicified specimen, 6, has been macerated in muriatic acid to expose it, and has suffered abrasion—neither the marginal ossicles, *b*, nor the reticular surface, *a*, shewing so clearly as they should do the real structure of the surface. At *a* a portion of the upper-side is seen, viz., impressions of three of the large granular ossicles, with their external deep pits (represented in the cast as circular elevations, with a minute central pit in each).

It is this specimen which so satisfactorily explains the meaning of the cast next to be described, and which, though differing specifically and from another formation, also helps materially to elucidate the specimens already described.

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† Upon a re-examination of this specimen I can detect no connection between the fragment of the tube and the disc, although it may have been connected.—E. B.

We dedicate this species to Professor J. Hall, the distinguished palæontologist of the New York survey.*

Locality and Formation.—Trenton limestone, City of Ottawa, and Lake St. John.

Collectors.—Sir W. E. Logan, E. Billings, J. Richardson.

II. Cyclocystoides Davisii, Salter.

C. ovalis ? uncialis et ultra, ossiculis marginalibus 48-49, *convexis, lævigatis, extus profunde excavates, simplicibus nec radiatim bilobis, margini recurvo, superficie obscure* 8, *radiato.*

This species certainly differs from the American one in that the number of marginal ossicles is much greater (forty-eight or forty-nine), while the ossicles themselves, instead of being granular, are smooth, and have the outer division much deeper, the margin being produced upwards as a distinct rim. Neither the division of the ossicles in this outer portion into two lobes, nor the separation of one ossicle from its neighbour, is at all distinctly marked; but just at the base of the deep excavation short-raised ridges indicate faintly these divisions, while the annular pits at the bottom are still deeper and more distinct than in the *C. Halli.*

This species shews the complete surface, on which about as many

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* Professor Hall in 1851 described a species of this genus in the palæontological part of Foster and Whitney's Report on the Geology of Lake Superior, page 209. Each of the specimens which he figures (see plate xxv. fig. 4, *a*, *b*, *c*, of the work cited) exhibits twenty-nine marginal plates. The smallest of ours (plate x. figure 5 of this decade) although exactly the size of the largest figured by Prof. Hall, has thirty-six, and so have our two largest. The Escanaba specimens are therefore most probably of a different species, which has not yet been named. The following is Prof. Hall's description:—

"This body consists of a ring, or a sac, the upper edge of which only appears, composed of numerous plates joining by their broader edges. The upper or exposed surface of the plates is sculptured or granulated, convex, and not closely joined together at the upper angles, presenting the appearance of somewhat quadrangular tubercles; exterior margin of each plate furnished with a thin wing-like expansion, marked by two diverging ridges.

"This curious body is evidently Crinoidean, from the character and structure of the plates. The ring presents an appearance very similar to the row of plates surrounding the valves which close the ovarian aperture in some Cystideans, but the number is far too great, being in one specimen twenty-nine, and apparently not less in the other. The inner faces of the plates moreover do not present any appearance, as if for the attachment of other plates or valves. It is possible that it may be the elevated marginal ring of some one of the sessile Crinoids, though the arrangement of the plates is more regular than in any species known to me.

"*Locality.*—Banks of the Escanaba river, two miles below the mouth of Indian creek, in the Trenton limestone."

radiations mark the margin as there are ossicles, and the centre of the flat disk is occupied by a star of about eight narrow rays, with a central depression. All of these markings are obscure, but were still capable of demonstration in the specimen (unfortunately since lost, after an accurate drawing had been taken).

The margin is peculiarly deep and raised like a rim all round; the outer half of the ossicles, being deprived of radiating ridges, combine to form a smooth channel. The deep-set annular pits shew on the cast as projecting rings with a central depression.

Locality.—May-Hill Sandstone of Prof. Sedgwick (Upper Llandovery Rock, Murchison), Presteign, Radnorshire, South Wales. Found by J. E. Davies, Esq., F.G.S.

Regarding the affinities of the fossils, the choice seems to be between Star-fishes and Cystideæ.

At first sight of the more perfect evidence thus brought together—for neither the Canadian or British specimens are complete without the other—the impression certainly was, that we had here a truly circular Star-fish, an extreme form of what is so often approached by some of the Gonialites of the chalk formation. We have figured one (figure 10) to illustrate this comparison, where the marginal ossicles of the disk and of the rays are so much alike, and the latter much shortened as to present nearly a circular outline.

In the loosely reticular skeleton of the disk there is an additional character, very common in Star-fish, but rare in Crinoids or Cystideæ. Against this supposition there is the peculiar excavation of the marginal ossicles, not for the attachment of large marginal spines, such as Goniaster and other star-fishes often exhibit on a small scale, but forming a hollow space, covered over with closely plated ossicles.

The discovery of the long tube, fig. 2, *b*, *c*, made (during the etching of the specimens) by our valued friend, Mr. Sowerby, threw still further doubt on this explanation. It appears as if continuous (though the connection cannot quite be traced,) with the marginal tesselated portions (*a*, *a*), and if this were the case there would be a channel running along the outer margin of the disk, and thence out freely at one end, a structure incompatible with that of any known Star-fish, or indeed any Echinoderm whatever. If on the other hand comparison be made with certain known forms of Cystideæ, although the reticular structure of the disk is abnormal, yet in the arrangement of the marginal ossicles there is a not indistinct resemblance to such forms of Cystideæ as *Pseudocrinites* (fig. 12), or perhaps still nearer to the Canadian form *Amygdalocystites*, described by one of the authors.

On the Palæozoic Bivalve ENTOMOSTRACA *of Canada.* By T. R. JONES, Esq., F.G.S.

I. BEYRICHIA LOGANI, Jones.

Plate XI. Figs. 1–5.

(*Annals of Natural History*, 3d series, vol. i. p. 244, plate ix. figs. 6–10.)

Length $\frac{1}{16}$, breadth $\frac{1}{26}$ inch.

This is a small *Beyrichia* of the unisulcate group ("Simplices," Annals Nat. Hist., 2 ser. vol. xvi. p. 85); variable in shape, from reniform to oblong; dorsal edge straight, extremities rounded and almost equal; ventral edge varying in its convexity. Surface of the valves somewhat depressed, most convex a little above the median line, sloping more gently to the ventral than to the dorsal margin; usually punctate, sometimes smooth; always bearing a distinct narrow depression on the dorsal region, usually on its anterior third; this dorsal notch reaches across a third or even more of the breadth of each valve. Ventral and terminal margins bordered by a narrow depressed rim.

I cannot regard the extreme shapes of the gregarious and innumerable individuals of this *Beyrichia* as typical of specific distinction. The general form, the relative convexity, and the dorsal notch are the more characteristic features.

a. Var. *reniformis.* The extreme of the kidney-shaped form is well shown in fig. 1, a specimen from Hawkesbury, where this shape occurs, with many of oblong outline, and others of intermediate shapes. The specimen here figured is strongly punctate: smooth specimens of this variety occur at Grenville.

b. Var. *leperditioides.* In fig. 5 we have one of the specimens in which the antero and postero-dorsal corners of the valves become modified towards the well-marked oblique dorsal angles of *Leperditia*.†

Locality and Formation.—Grenville and Hawkesbury; with the following species in the lower part of the Chazy.

Collector.—Sir W. E. Logan.

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† See p. 92 for further remarks on *B. Logani* and its varieties, in relation to *L. Canadensis.*

II. Leperditia Canadensis,* Jones. *a.* Var. nana.

Plate XI. Figs. 6, 7, 9, 10.

(*Annals of Natural History*, 3d series, vol. i. p. 244, plate ix. figs. 11–15.)

Length $\frac{1}{9}$, breadth $\frac{1}{13}$ inch.

Small; somewhat variable in shape, but always retaining the characteristic Leperditia-outline, with straight back, more or less obliquely-rounded belly, and sloping dorsal angles. Carapace usually short (the height or breadth being about two-thirds of the length), somewhat variable in the amount of convexity (thickness), which is usually greatest at the antero-ventral third. Surface smooth. Eye-tubercle generally well marked, and muscle-spot often distinct; but occasionally the latter becomes involved in the nuchal depression, and the former is sometimes obsolete.

This is the smallest form of *Leperditia* which I have yet met with. It occurs in great numbers, together with *Beyrichia Logani* in equal abundance, in a dark-grey friable limestone, mainly composed of these Entomostraca, fragments of trilobites and shells, at Grenville and near Hamiltonville in Hawkesbury, on the Ottawa. This Leperditia limestone forms part of a band of limestone, about two feet thick, which extends over a wide district†, and is of importance as marking the position of a continuous band of rock holding nodules of phosphate of lime which is beneath it; it belongs to the base of the Chazy limestone.

This variety of *L. Canadensis* occurs also in a dark-grey, crystalline, shelly limestone (of the Calciferous Sandrock) on the north side of Grande Isle,‡ in the St. Lawrence. In two hand specimens of this limestone a few separate valves and one pair of valves are present.

Beyrichia Logani and *Leperditia Canadensis*, var. *nana*, occur together in immense numbers, forming indeed a considerable portion of the limestone rock in which they are chiefly found. I believe that the former is not the young of the latter (although perhaps the differences of shape and structure are not greater than such as we find to occur between the young and adult forms of recent Entomostraca and other Crustacea), because, where the allied *Beyri-*

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* Referred to in Quart. Journ. Geol. Soc. vol. viii. p. 202 and p. 207.

† "This rock, having been quarried for lime-burning in several places, has been followed from Carillon to Grenville (thirteen miles)." Quart. Journ. Geol. Society, vol. viii. p. 207; and Logan's Report Geol. Surv. Canada, 1851–52, p. 18.

‡ Quart. Journ. Geol. Soc. vol. viii. p; 202; and Logan's Report, 1851–52, p. 15.

chiæ, such as *B. strangulata*,* *B. mundula*, and *B. simplex*, occur, even in as great numbers, in the rocks of other localities, the *Leperditiæ* are not found with them; the latter also occur unaccompanied by these *Beyrichiæ*, *L. Canadensis* itself being found alone in Grande Isle. The close resemblance in outline of some specimens of *B. Logani* (var. *B. leperditioides*, fig. 5) to the *Leperditiæ* is, I believe, merely a mimetic resemblance of outline, such as we find taking place among many groups, both of the lower and the higher animals.

b. Var. LABROSA.

Plate XI. Fig. 8.

Length $\frac{1}{6}$, breadth $\frac{1}{10}$ inch.

The extremities of the valves in this specimen from Hawkesbury are marked by a broad marginal depression, which is continued less strongly along the ventral border, and the antero-dorsal corner is more produced than usual.

This may be an individual modified by accidental circumstances of growth.

c. Var. LOUCKIANA.

Plate XI. Fig. 11.

Specimens of possibly the same species as the foregoing, but of a considerably larger size (often twice as large), occur in two other limestones, specimens of which Sir William Logan has confided to my examination.

Imbedded in bits of black fine-grained limestone from Louck's Mill, on the Castor River, in the township of Russell, are three glossy black valves, in good preservation, and of different sizes (one specimen being $\frac{3}{10}$ in. long and $\frac{2}{10}$ broad, the others being respectively $\frac{3}{20}$ in. and $\frac{3}{40}$ in. in length). In each of these the eye-spot is very distinct, and accompanied by a local ruggedness of the surface of the valve (not amounting to a sulcus); the valves are faintly rimmed.

This black limestone is referred to the Trenton in Geol. Survey Canada, Report, 1851-52, p. 73; but, according to a letter of later date from Sir W. E. Logan, it may be Birdseye limestone.

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* *Beyrichia strangulata* takes on a variety of forms (see Annals of Natural History 2nd series, vol. xvi. pl. 6, figs. 18–22) analogous to those of *B. Logani*.

d. Var. PAUQUETTIANA.

Plate XI. Fig. 12.

A small specimen of brownish, fine-grained limestone (weathering grey, and containing shells), from Pauquette's Rapids, Allumette Island, Ottawa River, contains one well-preserved brown coloured valve (fig. 12), $\frac{1}{4}$ inch long, $\frac{3}{20}$ inch broad, much like the largest specimen from Louck's Mill, but showing no marginal rim, and feeble traces only of the eye-spot and its accompanying depression. In this fragment of limestone (probably Trenton) smaller Entomostracous bivalves abound (see p. 99 and 100).

Except in the relative size, the form of the eye-spot, and the valve-margin (in which latter points one of these larger specimens varies from the others), the two sets of specimens (the large and the small) do not appear to disagree essentially, as far as my means of examination at present enable me to judge. At the same time, as we know that in some recent bivalved Entomostraca, different species and even subgenera may present a great similarity in their carapaces, it is possible that we have here a distinct specific form.

Mr. Conrad has briefly described,* under the name of *Cytherina fabulites*, a bivalved Entomostracan, from the Trenton limestone of Mineral Point, Wisconsin. This appears to be a *Leperditia* half an inch in length, and therefore surpassing in size the specimens under notice, to which it may be allied.

See Annals of Natural History, 3rd series, vol. i. p. 340, for descriptions of this and the following variety.

e. Var. JOSEPHIANA.

Plate XI. Fig. 16.

A small specimen of grey Trenton limestone, from the east side of St. Joseph's Island, Lake Huron, containing a Bryozoon, and weathering yellowish, bears a right valve of a *Leperditia* $\frac{21}{40}$ inch long, and $\frac{13}{40}$ inch broad; there is also a separate perfect carapace of the same form ($\frac{11}{40}$ inch thick) from the same limestone. The valves are of a light-brown color; the eye-spots are indistinct; the radiate markings of the muscle-spot are more visible on the left than on the right valve; the overlapping ventral edge is neither straight, nor symmetrically curved; the general form of the lower half of the carapace is rounded and bulky.

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* Proceedings of the Philadelphia Academy, 1843, vol. i. p. 332.

This Trenton form, which I have termed *L. Canadensis*, var *Josephiana*, may possibly be the same as Conrad's *L. fabulites;* if so, his name has priority.

f. Var. ANTICOSTIANA.

Plate XI. Fig. 17.

A piece of light-grey limestone (of the upper portion of the Hudson River group) from East Point, Anticosti, bears on its weathered surface encrinital ossicles and eleven separate valves of a *Leperditia* of different sizes; there is besides a separate perfect carapace of the same form, half an inch long, $\frac{13}{40}$ inch broad, and $\frac{8}{40}$ inch thick). These specimens have a rather short hinge-line, a well-marked ocular tubercle, and a muscle-spot visible only by its slightly darker tint. In some instances these valves appear to have a peculiar delicacy of make and substance; they slope rapidly from the central convexity; the ends of the carapace are thin, and the overlapping part of the right valve is distinctly central and neatly curved. This form differs from that of St. Joseph's in having a shorter hinge-line and a more prominent eye-spot; in the apparent absence of external radii to the muscle-spot; in the somewhat more delicate substance of the valves; in the lesser thickness of the carapace, in its attenuated edges before and behind, and in the symmetrical curvature of the overlapping ventral edge.

This neatly shaped *Leperditia* from Anticosti more nearly resembles its almost gigantic allies of Sweden* than do any other American *Leperditiæ* that I have seen. Still it is not without good points of relationship with *L. Canadensis*, and I have provisionally termed it *L. Canadensis*, var. *Anticostiana.*

The St. Joseph's form more nearly resembles the large varieties of *Leperditia Canadensis* (pl. xi. figs. 11 and 12) than do the Anticosti specimens; and as I did not feel authorized to separate specifically the little Grenville varieties, that from Louck's Mill, and that of Allumette, neither can I at present regard these comparatively large and well-grown specimens as belonging to another specific type.

Mr. Salter having lately favoured me with better specimens of the *Leperditia alta*, from Wellington Straits, than I had previously seen, I am enabled to point out, that though in size and general form the Arctic *L. alta* much resembles the *Leperditiæ* from Louck's Mill, Pauquette's Rapid, St. Joseph's, and Anticosti, it has a thinner shell, and a distinct muscular spot, with vascular radii; and further,

* Annals of Natural History, 2nd series, vol. xvii. p. 85, pl. 6.

it shows an inclination to vary extremely in the vertical dimensions of the carapace, so that in the same hand specimen, some individuals are ovate-oblong, and others narrow and pod-shaped. This habit of variability of outline is not apparent in the Canadian *Leperditiæ* above described.

Other localities in Canada are mentioned by Sir W. E. Logan and Mr. Murray for Entomostraca—probably *L. Canadensis* or allied forms, namely:—

Three miles above Lachine; in the Trenton limestone? *

Indian Lorette near Quebec; in the Birdseye limestone? †

Three or four miles from Montreal, in a line a little west of north; in the Birdseye limestone. ‡

Sheik's Island, Cornwall,§; with *Atrypa plena* in the Chazy.

Cornwall; in the Trenton limestone‖.

Lancaster; in the Black River limestone¶.

Winchester; in the Trenton limestone**.

III. Leperditia Anna, Jones.

Plate XI. Fig. 13.

(*Annals of Natural History*, 3d series, vol. i. p. 247, plate ix. fig. 18.)

Length $\frac{1}{6}$, breadth $\frac{1}{9}$ inch.

Small, convex; ovate-oblong, somewhat narrower in front than behind; the ventral curve nearly uniform; hinge-line straight; dorsal angles slightly truncate. Surface of valves most convex at the posterior third; smooth, thickly punctate, each of the little shallow circular pits having a minute central tubercle. Eye-spot distinct and raised.

Locality and Formation.—Several valves of this neatly-pitted *Leperditia* are present in a small hand-specimen of a hard dark colored concretionary limestone, under the zone of *Atrypa plena*, and belonging to the Calciferous Sandrock, from immediately behind the village of St. Ann's††, at the confluence of the Ottawa and St. Lawrence. This is probably the oldest known species of the genus.

Collector.—Sir W. E. Logan.

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* Quarterly Journal Geological Society, vol. viii. p. 205.

† Letter, Jan. 17, 1853. ‡ Letter.

§ Geol. Sur. Canada, Report, 1851–52, p. 70.

‖ *Ibid.* p. 70. ¶ *Ibid.* p. 71. ** *Ibid.* 72.

†† Quart. Jour. Geol. Soc. *loc. cit.;* and Geol. Sur. Canada, Report, 1851–52, p. 16

IV. Leperditia amygdalina, Jones.

Plate XI. Figs. 18, 19.

(*Annals of Natural History*, 3d series, vol. i. page 341.)

Several specimens of a dark-grey limestone, from near L'Orignal, are rich in separate valves of a handsome *Leperditia*, which at first sight has much the aspect of *Isochilina Ottawa;* but it is larger, blacker, and has a proportionally shorter hinge-line, the hinder portion of the valves being boldly and obliquely rounded, forming about one-third the length of the carapace; though the valves have a marginal rim, this is only on the two ends, being wanting below, where the middle third of the ventral border is turned in, overlapping on the right, and overlapped on the left side. The surface is smooth; the eye-spot prominent, and accompanied by a slight, irregular nuchal furrow; muscle-spot indistinct. The carapace is $\frac{3}{20}$ inch long, $\frac{5}{20}$ in. broad, and $\frac{8}{20}$ in. thick, and most convex at the anterior third.

Though numerous in the rock, the individuals are not massed together in layers, as are the *Isochilinæ* at L'Orignal, Grenville, and White Horse Rapids.

Locality and Formation.—One mile west of L'Orignal, Chazy.

Collector.—R. Bell.

Genus Isochilina*. *Subgenus of* Leperditia.

Equivalve; the margins of the valves meeting uniformly, not overlapping as in *Leperditia;* greatest convexity of the valves either central or towards the anterior portion. Eye-tubercle present. Muscular spot not distinct externally.

V. Leperditia (Isochilina) Ottawa, Jones.

Plate XI. Fig. 14.

(*Annals of Natural History*, 2d series, vol. i. p. 248, plate x. fig. 1.)

Length $\frac{1}{6}$, breadth $\frac{1}{10}$ inch.

Leperditia-like in outline, somewhat elongate, smooth; marginal border distinct, frequently seen to be marked by a line of small, distinct pits; eye-spot distinctly raised.

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* *Equal lip.*

From the canal at Grenville. Gregarious; the separated valves forming a thin layer about half an inch thick, in a dark-grey limestone of the Calciferous Sandrock, a foot or two beneath the "two-foot limestone," and traceable for some miles.

In several specimens of Leperditia rock from the Chazy limestone near the N.W. corner of the township of L'Orignal, I have recognized the *Isochilina Ottawa*, under similar conditions to those in which it occurs at the Grenville canal, except that in one specimen it is associated with a *Modiolopsis*-like shell. I have only to remark, that when the shell is broken off, the casts of the valves show a distinct muscle-spot (concave on the inner side of the valve) with numerous radii.

Collectors.—Sir W. E. Logan, J. Richardson, R. Bell.

VI. Leperditia (Isochilina) gracilis, Jones.

Plate XI. Fig. 15.

(*Annals of Natural History*, 3d series, vol. i. p. 248, plate x. fig. 2.)

Length $\frac{1}{7}$, breadth $\frac{1}{12}$ inch.

Carapace sub-rhomboidal, narrow and slender when compared with the *Leperditiæ* proper; anterior extremity obliquely rounded, with the antero-dorsal angle produced, slightly obtuse; posterior extremity rounded, with the postero-dorsal angle obliquely truncate. Ventral curve uniform. Surface of valve convex centrally, black, shining, smooth, sparsely punctate; the pitting partial often obscure, or nearly obsolete. Depressed margin broad, in many specimens bearing a row of rounded pits (about thirty-two), which are represented on the inside of the rim by corresponding raised obtuse points.

Locality and Formation.—Gregarious; in loose fragments of a black, fine-grained fœtid limestone from the White Horse Rapids, Isle Jesus, referred, with doubt, to the Trenton limestone in the Quart. Journ. Geol. Soc., vol. viii. p. 205, but to the Birdseye limestone in a letter of later date from Sir W. E. Logan. The disunited valves lie matted together, and sprinkled with minute iridescent crystals of pyrites, in a thin layer or layers in the rock.

Collector.—Sir W. E. Logan.

Genus Cytheropsis, M'Coy.

This generic appellation is affixed to a bivalved Entomostracan (figure 2, plate 1. L.) in the 'Systematic Description of the British

Palæozoic Fossils in the Geological Museum of the University of Cambridge,' 1855, but neither the characters of the genus nor of the fossil are described, owing probably to the author not having had time to add this description to the great work referred to.

Cytheropsis appears to me to be a useful term for the distinction of those palæozoic Entomostraca that do not closely assimilate either to *Leperditia* or *Beyrichia*, but much resemble in outline and size many of the *Cytheres* of the existing seas, differing however from them in sometimes having eye or muscle-spots, and other peculiar features, such as a comparatively great thickness of the valves. Though based chiefly on negative characters, this group may for the present be conveniently referred to as being generic.

I have noticed several minute Entomostraca in the Silurian rocks of Wales and Sweden, which may probably belong to this group.

VII. Cytheropsis concinna, Jones.

(*Annals of Natural History*, 3d series, vol. i. p. 249, plate x. figs. 3, 4.)

Length $\frac{1}{17}$, breadth $\frac{1}{33}$ inch.

Carapace subcylindrical, tapering anteriorly; ends rounded; back straight; dorsal angles slightly truncate; ventral edge of right valve overlapping that of the left. Surface smooth, shining, light-brown, partially pitted. In some specimens a very slight marginal rim is traceable.

Locality and Formation.—Many specimens, both of double and single valves, in the Trenton? limestone of Pauquette's Rapids, Allumette Island, Ottawa River.

I have had some doubt whether this may not be the young of a *Leperditia;* but it has no eye-spot and is too narrow, young *Leperditiæ* being proportionally broader than the adults.

Collector.—Sir W. E. Logan.

VIII. Cytheropsis siliqua, Jones.

(*Annals of Natural History*, 3d series, vol. i. p. 249, plate x. fig. 6.)

Length $\frac{1}{12}$, breadth $\frac{1}{40}$ inch.

Carapace-valves long, narrow, pod-like or skiff-shaped; ends acute, one much sharper and more tapering than the other; dorsal edge long and straight; ventral edge convex; one valve overlapping the other. Smooth, shining, brown.

Two separate valves of this curious and rather obscure form (so much resembling *Bairdia siliqua* of the Chalk, and the recent *B. Minna*) occurred in the limestone from Pauquette's Rapids.

IX. Cytheropsis rugosa, Jones.

(*Annals of Natural History*, 3d series, vol. i. p. 249, plate x. fig. 5.)

Length $\frac{1}{30}$, breadth $\frac{1}{46}$ inch.

Small, convex, subreniform, broad, rounded at both ends, the anterior one of which is smaller than the other. Coarsely sculptured with broad shallow pits. One specimen, showing the two valves united, and of a light-brown color, occurred with the many other Entomostraca in the small specimen of limestone from Pauquette's Rapids.

Locality and Formation.—Pauquette's Rapids.

Collector.—Sir W. E. Logan.

To give a general view of the distribution of the known species and varieties of Bivalved Entomostraca in the Lower Palæozoic strata of the United States, Canada, and Arctic America, the following Table is appended:—

TABLE OF THE PALÆOZOIC BIVALVED ENTOMOSTRACA OF NORTH AMERICA.A

Genera and Species.	Localities.	New York Groups.	British groups.
1. Beyrichi rugulifera, *Jones*			
2. —— sigillata, *Jones*			
3. —— clathrata, *Jones*	Beechey Island		Wenlock group.
4. —— plagosa, *Jones*			
5. Leperditia gibbera, *Jones*			
6. —— Arctica, *Jones*	Wellington Straits		
7. —— marginata, *Keyserling*	Rupert's Land (and Petschora Land)		?
8. —— alta, *Conrad*	Schoharie (and Wellington Straits)	Coralline Limestone & Tentaculite Limestone (Lower Helderberg)	
5*a*.—— gibbera, var. scalaris	Williamsville and Pennsylvania	Waterlime	Wenlock group.
9. Beyrichia Maccoyiana, *Jones*	Pennsylvania	Onondaga Salt-group	
10. —— Pennsylvanica, *Jones*	Pennsylvania		
11. Leperditia Pennsylvanica, *Jones*	Pennsylvania	Clinton group	
12. Beyrichia lata, *Vanuxem*	Oneida County, &c.		Llandovery group.
13. Isochilina cylindrica (?) *Hall*	Medina, &c.	Medina Sandstone	
20*a*.Leperditia Canadensis (var)	Anticosti	Hudson River group	
14. Leperditia fabulites, *Conrad*	Wisconsin	Trenton Limestone	
15. Cytheropsis concinna, *Jones*			
16. —— siliqua, *Jones*	Allumette Island, Ottawa		
17. —— rugosa, *Jones*		Trenton Limestone	
20*a*.Leperditia Canadensis (var.)			
20*a*.—— —— (var.)	St. Joseph's Island		
18. —— ovata, *Jones*	Pennsylvania	Blackriver Limestone	Llandeilo and Caradoc groups.
20*a*.—— Canadensis (var.)	Louck's Mills, Canada	Birdseye Limestone	
19. Isochilina gracilis, *Jones*	Isle Jesus, Canada		
20. Leperditia Canaden. (var. *nana*) *Jones*	Grand Isle, Grenville, & Hawkesbury		
21. Beyrichia Logani, *Jones*	Grenville and Hawkesbury	Chazy Limestone	
22. Isochilina Ottawa, *Jones*	Grenville, Canada		
23. Leperditia amygdalina, *Jones*	L'Orignal, Grenville		
24. —— Anna, *Jones*	St. Ann, Canada	Calciferous Sandrock	

Two other forms of Entomostraca, with which I am as yet unacquainted, are described by Prof. J. Hall; namely *Cytherina spinosa*, Pal. New York, vol. ii. p. 317, pl. 67, fig. 17–21, and *Beyrichia symmetrica*, *loc. cit.* f. 16, from the Niagara Shale, Lockport. Hall also mentions and figures another form (*op. cit.* vol. i. p. 44, pl. 10, f. 12) from the Birdseye Limestone and Trenton Limestone.

EXPLANATION OF FIGURES. Plate XI.

Fig. 1. *B. Logani* (var. *reniformis*); magnified 4 times: *a*, right valve; *b*, dorsal view; *c*, anterior view. From Hawkesbury.

Fig. 2. *B. Logani;* magnified 4 times: *a*, left valve; *b*, dorsal, and *c*, posterior view. From Hawkesbury.

Fig. 3. *B. Logani;* magnified 4 times: *a*, left valve; *b*, ventral, and *c*, posterior view. From Grenville.

Fig. 4. *B. Logani;* magnified 4 times: *a*, right valve; *b*, dorsal view. From Hawkesbury.

Fig. 5. *B. Logani* (var. *leperditoides*); magnified 4 times: *a*, right valve; *b*, anterior view. From Grenville.

Fig. 6. *Leperditia Canadensis* (var. *nana*); magnified 4 times: *a*, left valve; *b*, ventral, and *c*, posterior view. From Grenville.

Fig. 7. *L. Canadensis* (var. *nana*); magnified 4 times: *a*, right valve; *b*, ventral view. From Grenville.

Fig. 8. *L. Canadensis* (var. *labrosa*): magnified 4 times: *a*, left valve; *b*, ventral, and *c*, anterior view; *d*, portion of surface of *a*, very highly magnified ($\times$ 75).

Fig. 9. *L. Canadensis* (var. *nana*); magnified 4 times: *a*, left valve; *b*, dorsal, and *c*, anterior view. From Grande Isle.

Fig. 10. *L. Canadensis* (var. *nana*); dorsal view of the united valves (nearly closed); magnified 4 times. From Grande Isle.

Fig. 11. *L. Canadensis* (var. *Louckiana*); *a*, right valve, magnified 2 diameters; *b*, ventral view; *c*, anterior view; *d*, outline, magnified 4 times. From Louck's Mill.

Fig. 12. *L. Canadensis* (var. *Pauquettiana*): *a*, right valve, magnified 2 diameters; *b*, the ventral, and *c*, the anterior view, showing the inner flange of the ventral edge; *d*, outline, magnified 4 times. From Pauquette's Rapids, Allumette Island.

Fig. 13. *L. Anna;* magnified 4 times: *a*, right valve; *b*, ventral, and *c*, anterior view; *d*, portion of surface of *a*, highly magnified ($\times$ 25). From St. Anne's.

Fig. 14. *Isochilina Ottawa;* magnified 4 times: *a*, left valve; *b*, anterior, and *c*, ventral view. From Grenville Canal.

Fig. 15. *I. gracilis;* magnified 4 times: *a*, right valve; *b*, anterior view, and *c*, ventral; *d*, magnified portion of the marginal rim. From White Horse Rapids.

Fig. 16. *L. Canadensis* (var. *Josephiana*); natural size: *a*, right valve; *b*, ventral, and *c*, anterior view. From St. Joseph's Island.

Fig. 17. *L. Canadensis* (var. *Anticostiana*); natural size: *a*, left valve; *b*, ventral view. From Anticosti.

Fig. 18. *L. amygdalina;* natural size: *a*, right valve; *b*, ventral, and *c*, anterior view. From L'Orignal.

Fig. 19. *L. amygdalina;* natural size: *a*, left valve; *b*, ventral, and *c*, anterior view From L'Orignal.

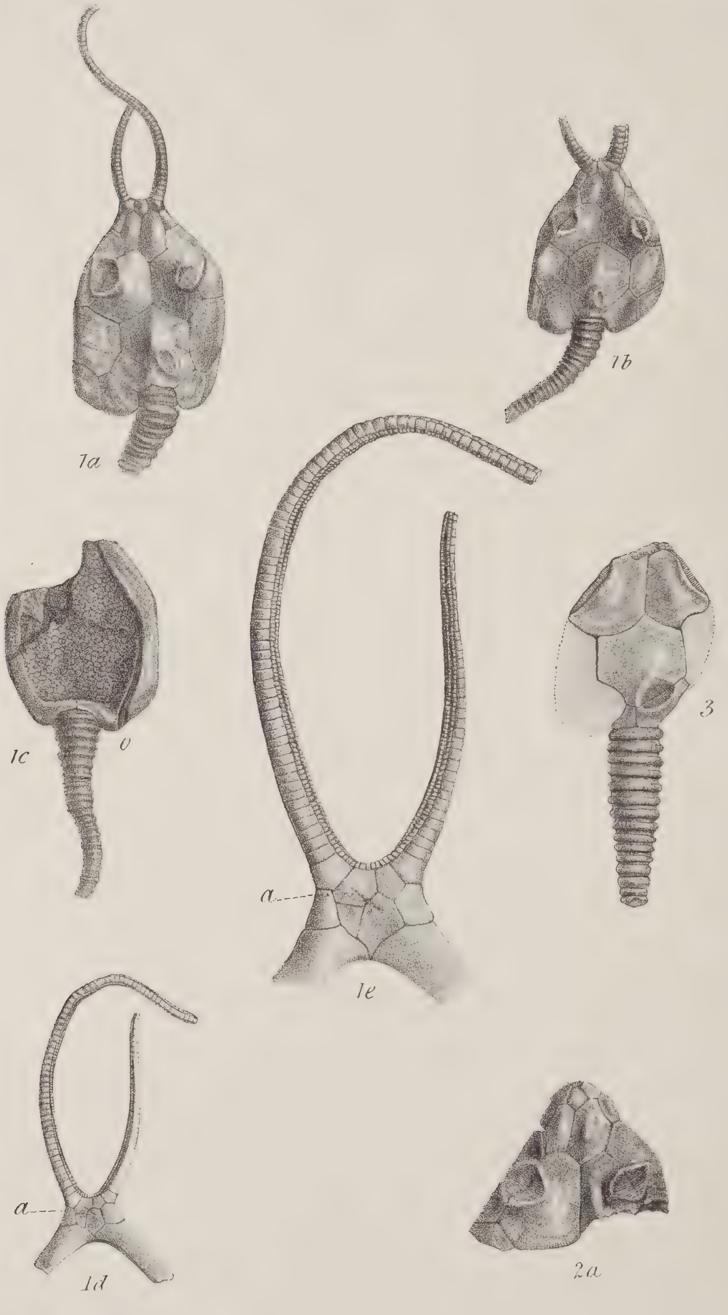

1a
1b
1c
o
1e
a
3
a
1d
2a

PLATE I.

Pleurocystites squamosus (page 49).

Figures 1*a* and 1*b*. Dorsal views of two specimens.

" 1*c*. Ventral view of a specimen, shewing the plated integument and strong borders formed by the folding over of the dorsal plates; *o*, the mouth.

" 1*d*. Ventral view of the upper part of the cup and arms of a specimen of this species, the remainder of which is completely buried in the stone.

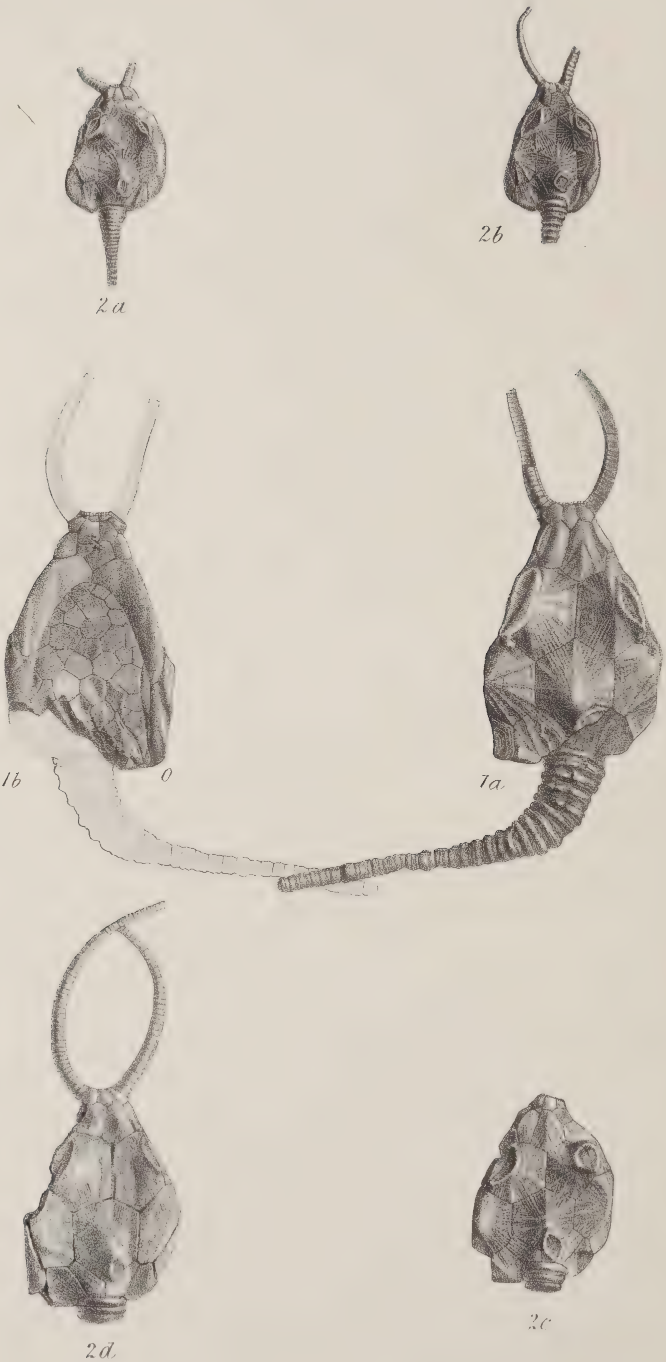
" 1*e*. View of the same, enlarged; at *a* is the small sub-apical aperture. It is represented too large in the figure.

Pleurocystites robustus (page 49).

Figure 2*a* shews a fragment of the upper part of a specimen. From the position in which the artist viewed the specimen, the left rhomb in the figure appears too angular on the upper side.

Pleurocystites Anticostiensis (page 52).

Figure 3. Dorsal view of an imperfect specimen of this species.


2a
2b
1b
0
1a
2d
2c

PLALE II.

Pleurocystites filitextus (page 50).

Figure 1*a* is a specimen which has the column and a portion of the arms firmly attached to a piece of limestone. The greater part of the body however is loose, and can be removed in one piece, giving a view of the ventral side.

" 1*b* is the ventral side, shewing the large plates of the integument, and obscurely the small aperture near the apex. The specimen is somewhat distorted by pressure, so that the true form of the rhombs cannot be made out. *o*, the mouth.

Pleurocystites elegans (page 51).

Figures 2*a*, 2*b*, 2*c*, and 2*d*? are dorsal views of this species. It is doubtful whether 2*d* should be referred to this species or to the thickly striated varieties of *P. filitextus*. The crushed condition of this, and indeed of all the specimens, renders it most difficult to decide when the species are so closely allied.

GEOLOGICAL SURVEY OF CANADA.

DECADE 3. Pl 3
LOWER SILURIAN
Trenton

Tuffen West del. et lith.

West & C° imp

PLATE III.

Glyptocystites multiporus (page 54).

Figure 1*a*. The plates of the calyx spread out; the dotted lines which extend from the top to the bottom indicate the course of the arms.

" 1*b*. Plates of the genus *Echino-encrinites*, figured here for comparison.

" *d*. Anterior view of a perfect specimen of *G. multiporus*.

" E. The left side of the same specimen.

" F. The dorsal or posterior side of another specimen.

" *c*. The right side.

" *g*. The apex, enlarged.

" *i*. The base.

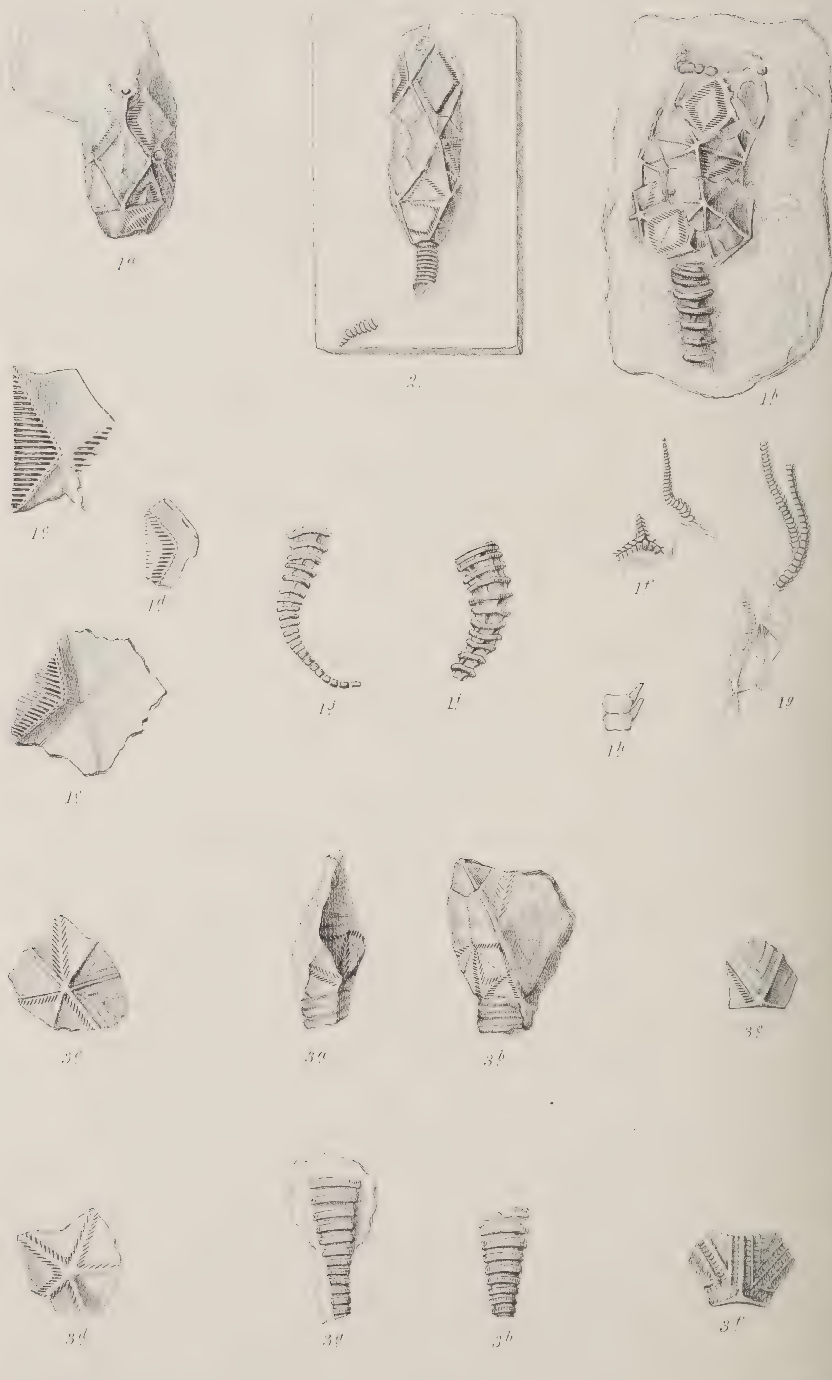
" *n*. A specimen with the column attached; anterior view.

" L. One of the rhombs enlarged.

" *g* and *k*. Sections shewing the depth to which the partitions of the rhombs entered.

GEOLOGICAL SURVEY OF CANADA.

DECADE 3 Pl 4.
LOWER SILURIA
(Trenton)



Tuffen West, del. et lith.

West & Co imp.

PLATE IV.

GLYPTOCYSTITES LOGANI (page 57).

Figures 1*a* and 1*b* are dorsal views of two specimens.

" 1*c*, 1*d* and 1*e* are enlarged views of the interiors of three rhombiferous plates, shewing that the pores penetrate through, and that each on the inside is surrounded by an exceedingly thin elevated border.

" 1*f*. A portion of the ambulacral groove of the apex, and one of the pinnulæ enlarged.

" 1*g*. A fragment with two of the pinnulæ.

" 1*i* and 1*j*. Fragments of columns. The specimens are crushed, and do not clearly shew the spiral arrangement.

G. LOGANI, *var.* GRACILIS (page 59).

Figure 2. Dorsal side of the only specimen collected.

GLYPTOCYSTITES FORBESI (page 59).

Figures 3*a* and 3*b*. Two views of the base of a specimen.

" 3*c* and 3*d*. Imperfect plates, to shew the character of the rhombs.

" 3*d* has the remains of four rhombs.

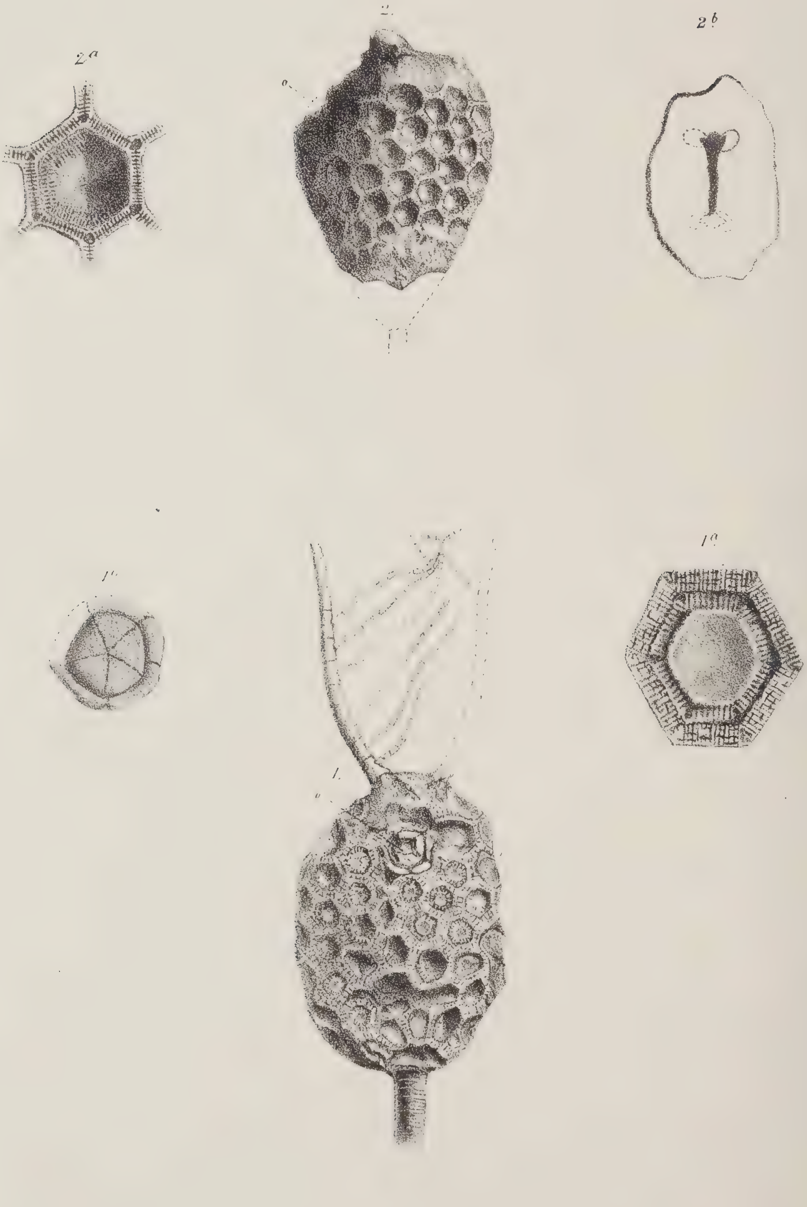
" 3*e* is the basal plate of the right side.

" 3*f* is the hexagonal basal plate of the anterior side.

" 3*g* and 3*h*, round columns, with the edges of the large joints pitted.

GEOLOGICAL SURVEY OF CANADA.

DECADE 3. Pl. 5.
LOWER SILURIAN
(Trenton.)



Horace S. Smith, del. et. lith.

Printed by Hullmandel & Walton.

PLATE V.

Comarocystites punctatus (page 61).

Figure 1. Anterior view of a large specimen, with one arm and the pinnulæ attached. *o*, the mouth.

" 1*a*. A plate of the same, enlarged, to shew the peculiar striation.

" 1*b*. The valvular apparatus of the mouth, enlarged.

" 2. View of the left side of another specimen.

" 2*a*. A plate of same, enlarged.

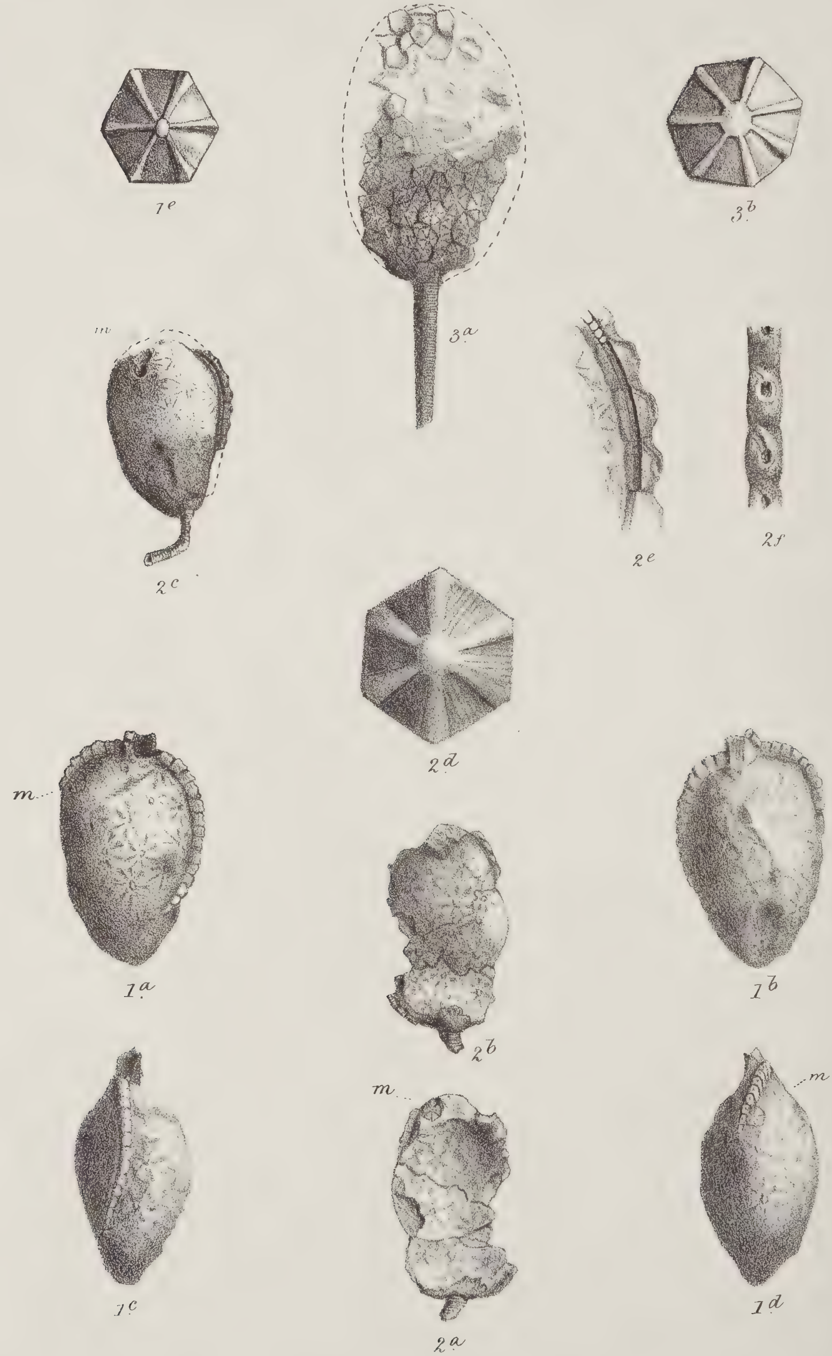
" 2*b*. Outline of the summit, shewing the positions of the bases of the arms, and the ambulacral groove between them.

Dr. E. Van Cortlandt of Ottawa, has kindly sent me from his cabinet two of the best specimens of *C. punctatus* that I have yet seen, both of which have the mouth furnished with six valves instead of five, and it thus appears that the number is variable as it is in the Crinoid *Caryocrinus ornatus* (Say). Where the plates are very perfect they are striated in the manner represented by fig. 2*a*, and the ridges between the plates are quite sharp and imperforate. It is probable, therefore, that in no case are the pores visible externally, unless where the surface is worn. This latter fact, first clearly exhibited by Dr. Van Cortlandt's specimens, shews that *Camarocystites* and *Palæocystites* are closely allied genera.

These specimens did not reach me until after the foregoing sheets had been printed, otherwise they would have been noticed in the body of the work.

GEOLOGICAL SURVEY OF CANADA.

DECADE 3 Pl. 6.
LOWER SILURIAN.
(Trenton.)



Horace S. Smith, del. et. lith.

Printed by Hullmandel & Walton.
Lithogrs. to the War Department

PLATE VI.

Amygdalocystites florealis (page 63).

Figure 1*a*. The left side of a specimen; *m*, the mouth.
" 1*b*. Right side of the same.
" 1*c*. Posterior view.
" 1*d*. Anterior views. The groove is not clearly shown in this specimen.
" 1*e*. One of the plates enlarged.

Amygdalocystites tenuistriatus (page 64).

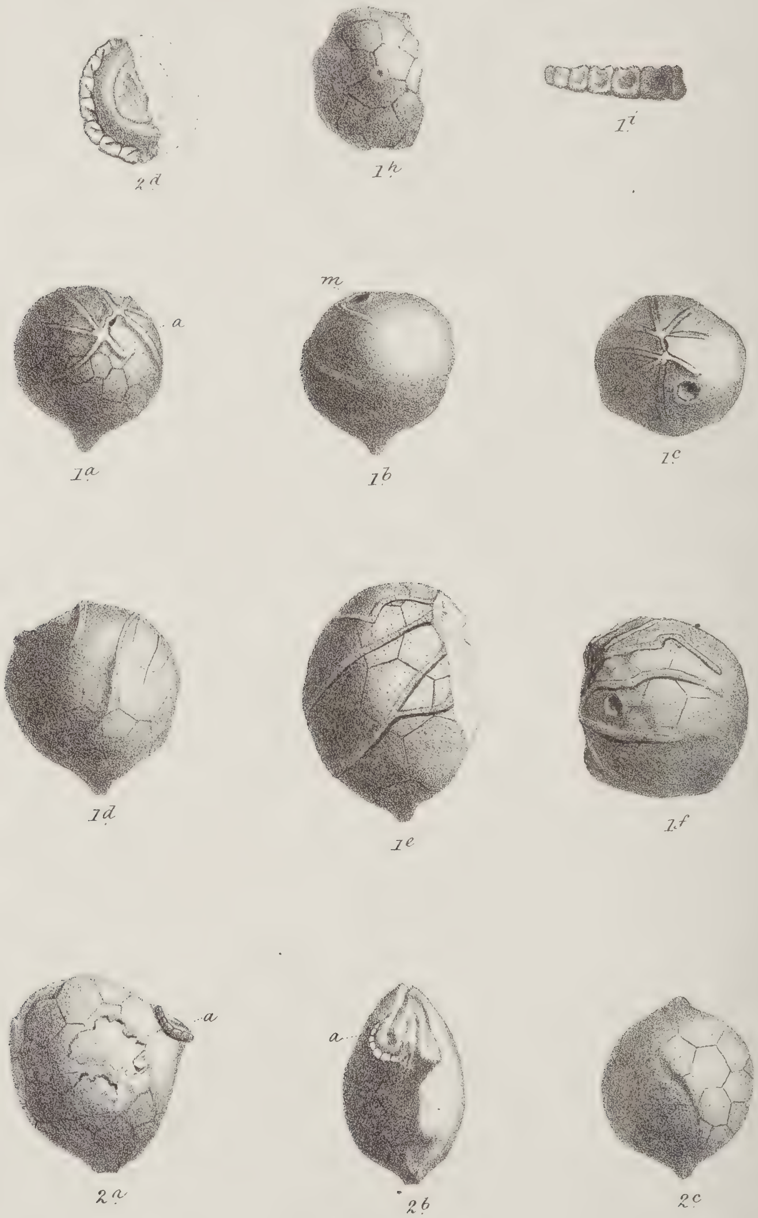
Figures 2*a*, 2*b*. Right and left side of the Ottawa specimen; *m*, the mouth.
" 2*c*. Left side of a specimen from Belleville, shewing a portion of the arm.
" 2*e*. The arm enlarged, shewing the ambulacral groove.
" 2*f*. View of the top of the arm, shewing the articulating cavities of the pinnulæ, and the branches of the ambulacral grooves leading to them.
" 2*d*. A plate enlarged, shewing the striæ.

Amygdalocystites radiatus (page 65).

Figure 3*a*. A specimen crushed flat, imbedded in stone.
" 3*b*. One of the plates enlarged. The specimen is worn, and does not shew the granular surface of the spaces between the radiating ridges.

GEOLOGICAL SURVEY OF CANADA.

DECADE 3. Pl. 7.
LOWER SILURIAN
(Chazy.)



Horace S. Smith, del. et lith.

Printed by Hullmandel & Walton,
Lithogrs. to the War Department.

PLATE VII.

Malocystites Murchisoni (page 66).

Figure 1*a*. Right side of a specimen, shewing the ambulacral orifice and the eight arms.

" 1*b*. The left side, shewing the position of the mouth, *m*.

" 1*c*. Vertical view of the ambulacral orifice.

" 1*d*, 1*e*. Left sides of two other specimens.

" 1*f*. Apex of 1*e*.

" 1*h*. Base of 1*d*, shewing the three basal plates.

" 1*i*. Portion of an upper surface of an arm magnified.

Malocystites Barrandi (page 67).

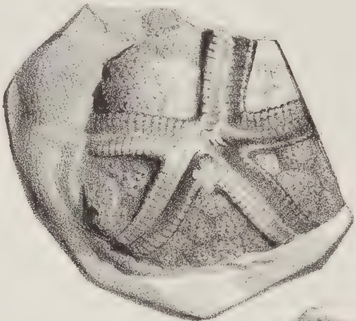
Figure 2*a*. View of the left side of a specimen; *a*, the arm.

" 2*b*. Posterior view of the same.

" 2*c*. Anterior view of another specimen.

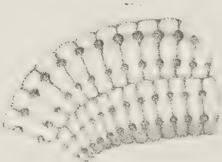
" 2*d*. The arm of 2*a* magnified, shewing the short branches of the ambulacral furrow to the bases of the pinnulæ.

1.



2

2a

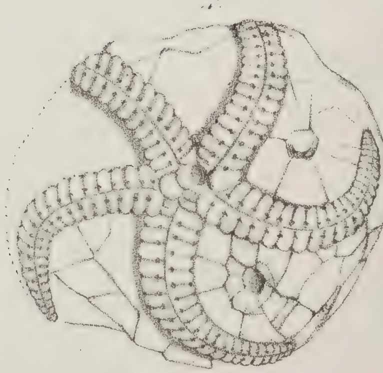


1a

3a

3.

4a



4.

C. R. Bone, del. et lith.

Printed by Hullmandel & Walton.

PLATE VIII.

EDRIOASTER BIGSBYI (page 82).

Figure 1. Upper side of a specimen partly embedded in stone.

" 1*a*. A polished section through the mouth and two of the grooves, showing that the pores penetrate through.

" 2. Fragment of a crushed specimen, showing two of the rays.

" 2*a*. A portion of figure 2 enlarged to show the pores.

AGELACRINITES DICKSONI (page 84).

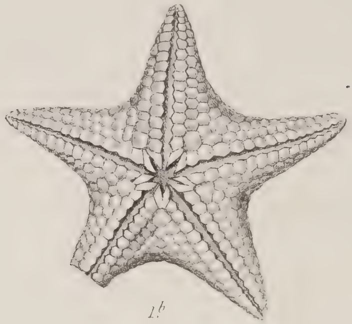
Figure 4. The original specimen discovered by Dr. Bigsby, now in the Museum of Practical Geology, Jermyn Street, London.

" 4*a*. The same enlarged.

" 3. View of a different specimen, in collection Geological Survey of Canada.

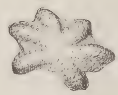
" 3*a*. The same enlarged.

DECADE 3. Pl. 9.
LOWER SILURIAN.
(Trenton & H. R.)



1b

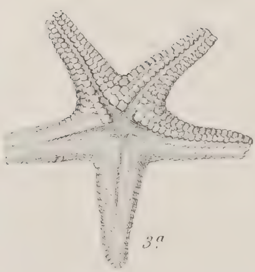
1a



2c

2b

2a



3a

3b

Tuffen West, del et lith.

West & Co. imp.

PLATE IX.

PALASTERINA STELLATA (page 76).

Figure 1*a*. The specimen natural size.
" 1*b*. The same enlarged.

PALASTERINA RUGOSA (page 77).

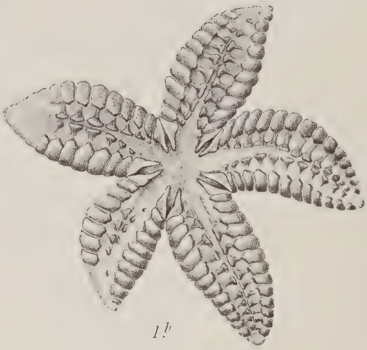
Figure 2*a*. Dorsal view of a specimen from the Hudson River group, Anticosti.
" 2*b*. Fragment of another individual.
" 2*c*. One of the plates enlarged.

PETRASTER RIGIDUS (page 80).

Figure 3*a*. Ventral view of an imperfect specimen.

Fig. 3*a* appears to be the dorsal side of an individual of this species with the plates along the centre of the rays removed.

1a

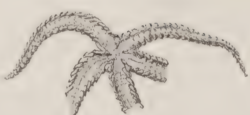


1b

3a

3c

3b



4b

3d

4c

2.

4a

Tuffen West, del et lith.

West & C° imp.

PLATE X.

Stenaster Salteri (page 78).

Figure 1*a*. Ventral view of a specimen collected at Belleville.
" 1*b*. The same enlarged.

Stenaster pulchellus (page 79).

Figure 2. Ventral view of the only specimen collected.

Tæniaster spinosus (page 81).

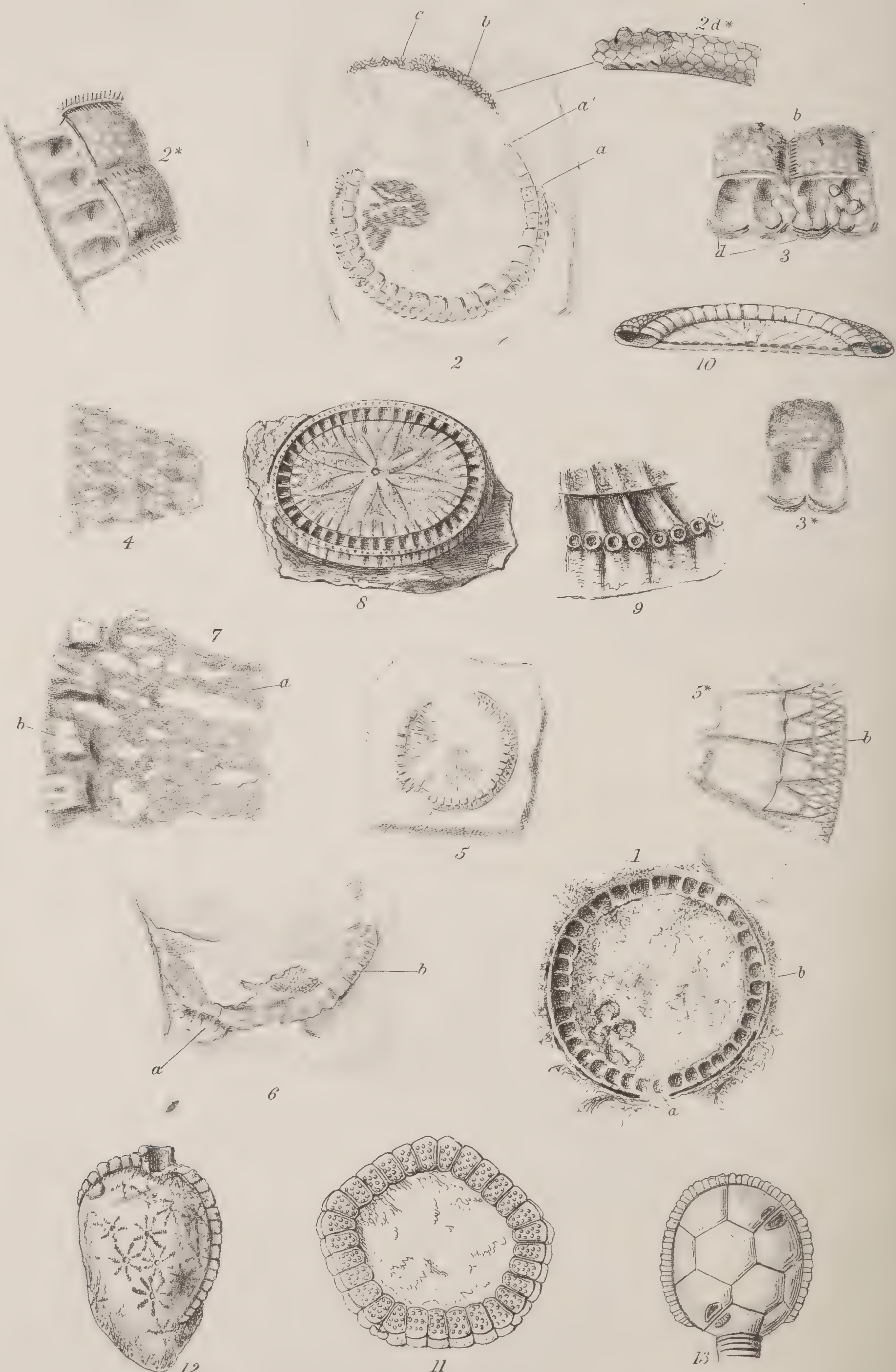
Figure 3*a*. Ventral view of a small specimen.
" 3*b*. The same enlarged.
" 3*c*. Another specimen, with the rays bent upwards.
" 3*d*. The same enlarged.

Tæniaster cylindricus (page 81).

Figure 4*a*. Dorsal view of a specimen.
" 4*b*. Ventral view of a different specimen.

GEOLOGICAL SURVEY OF CANADA.

DECADE 3. Pl. 10 bis
LOWER SILURIAN
(Trenton.)



J. De C. S. and J. W. Salter del.

J. De C. Sowerby sc.

PLATE X. (bis.)

Cyclocystoides Halli (page 86).

Figure 1. Impression of the marginal plates in a fragment of limestone.
" 2. A different specimen, shewing twenty-six of the marginal plates. *a* and *b*. the tube. 2*d**, tube enlarged. 2*, marginal plates enlarged.
" 3. Marginal plates enlarged.
" 4. A portion of the disc enlarged.
" 5. A small specimen nearly perfect. 5*, portion of margin enlarged.
" 6. Portion of a specimen partly destroyed by the application of acid.
" 7. Part of 6 enlarged.

Cyclocystoides Davisii (page 89).

Figure 8. Cast of a specimen with margin perfect.
" 9. Portion of margin magnified.
" 10. Ideal section of *Cyclocystoides*.
" 11. Pentagonal Star-fish.
" 12. *Amygdalocystites florealis*.
" 12. *Pseudocrinites magnificus*.

The three latter figures are given for comparison.

GEOLOGICAL SURVEY OF CANADA.

DECADE. 3. Pl. 11
LOWER SILURIAN.

Geo. West del. & lith.

West & Co. imp.

PLATE XI.

(Page 91—102.)

Fig. 1. *B. Logani* (var. *reniformis*) ; magnified 4 times : *a*, right valve ; *b*, dorsal view ; *c*, anterior view. From Hawkesbury.

Fig. 2. *B. Logani ;* magnified 4 times : *a*, left valve ; *b*, dorsal, and *c*, posterior view. From Hawkesbury.

Fig. 3. *B. Logani ;* magnified 4 times : *a*, left valve ; *b*, ventral, and *c*, posterior view. From Grenville.

Fig. 4. *B. Logani ;* magnified 4 times : *a*, right valve ; *b*, dorsal view. From Hawkesbury.

Fig. 5. *B. Logani* (var. *lepeditoides*) ; magnified 4 times : *a*, right valve ; *b*, anterior view. From Grenville.

Fig. 6. *Leperditia Canadensis* (var. *nana*) ; magnified 4 times : *a*, left valve ; *b*, ventral, and *c*, posterior view. From Grenville.

Fig. 7. *L. Canadensis* (var. *nana*) ; magnified 4 times : *a*, right valve ; *b*, ventral view. From Grenville.

Fig. 8. *L. Canadensis* (var. *labrosa*) ; magnified 4 times : *a*, left valve ; *b*, ventral, and *c*, anterior view ; *d*, portion of surface of *a*, very highly magnified (× 75).

Fig. 9. *L. Canadensis* (var. *nana*) ; magnified 4 times : *a*, left valve ; *b*, dorsal, and *c*, anterior view. From Grande Isle.

Fig. 10. *L. Canadensis* (var. *nana*) ; dorsal view of the united valves (nearly cloeed) ; magnified 4 times. From Grande Isle.

Fig. 11. *L. Canadensis* (var. *Louckiana*) ; *a*, right valve, magnified two diameters ; *b*, ventral view ; *c*, anterior view ; *d*, outline, magnified 4 times. From Louck's Mill.

Fig. 12. *L. Canadensis* (var. *Pauquettiana*) ; *a*, right valve, magnified 2 diameters ; *b*, the ventral, and *c*, the anterior view, showing the inner flange of the ventral edge ; *d*, outline, magnified 4 times. From Pauquette's Rapids, Allumette Island.

Fig. 13. *L. Anna ;* magnified 4 times : *a*, right value ; *b*, ventral, and *c*, anterior view ; *d*, portion of surface of *a*, highly magnified (× 25). From St. Anne's.

Fig. 14. *Isochilina Ottawa ;* magnified 4 times : *a*, left valve ; *b*, anterior, and *c*, ventral view. From Grenville Canal.

Fig. 15. *I. gracilis ;* magnified 4 times . *a*, right valve ; *b*, anterior view, and *c*, ventral , *d*, magnified portion of the marginal rim. From White Horse Rapids.

Fig. 16. *L. Canadensis* (var. *Josephiana*) ; natural size : *a*, right valve ; *b*, ventral, and *c*, anterior view. From St. Joseph's Island.

Fig. 17. *L. Canadensis* (var. *Anticostiana*) ; natural size : *a*, left valve ; *b*, ventral view. From Anticosti.

Fig. 18. *L. amygdalina ;* natural size : *a*, right valve ; *b*, ventral, and *c*, anterior view. From L'Orignal.

Fig. 19. *L. amygdalina ;* natural size : *a*, left valve ; *b*, ventral, and *c*, anterior view. From L'Orignal.

GEOLOGICAL SURVEY OF CANADA.

SIR W. E. LOGAN, F.R.S., DIRECTOR.

FIGURES AND DESCRIPTIONS

OF

CANADIAN ORGANIC REMAINS.

DECADE IV.

Montreal:

PRINTED BY JOHN LOVELL, ST. NICHOLAS STREET.

1859.

NOTICE.

THE plates of the present Decade were all drawn on stone by Mr. H. SMITH, at the office of the Survey, and printed by Mr. MATHEWS, the well known lithographer of Montreal. The Decade, like those which have preceded it, will be placed in the hands of respectable booksellers for sale at a moderate price; and, judging from the demand for the first one issued, there is good reason to believe that the whole edition of two thousand copies will be ultimately disposed of, and that the work will repay the expenses of publication.

W. E. LOGAN.

MONTREAL, 1st May, 1859.

PREFACE.

The following Decade contains descriptions of all the Crinoids of the Lower Silurian rocks of Canada, of which specimens have been procured in such a state of preservation as to admit of their being characterized. Of these, five belong to the Chazy limestone, and the remainder to the Birdseye, Black River, Trenton, and Hudson River formations. Altogether we have about fifty species, including several which have been as yet recognized by their columns only.

Of the thirteen genera to which I have referred these species two, *Rhodocrinus* (Miller,) and *Glyptocrinus* (Hall), occur in the Silurian rocks of Europe, but none of the species are common to both sides of the Atlantic. Five of the genera, *Heterocrinus*, *Glyptocrinus*, *Dendrocrinus*, *Lecanocrinus*, and *Rhodocrinus*, have been found in the State of New York, the first two in the Lower Silurian and the last three in the Upper Silurian. None of the other eight genera have been noticed as occurring out of Canada, although it is highly probable that some, if not all of them, will, in course of time, be discovered in the Silurian rocks of the adjacent countries.

The most remarkable species is the one to which we have given the name of *Blastoidocrinus carchariædens*. This fossil, by the structure of its ventral surface, is closely allied to *Pentremites*, the typical genus of the order Blastoideæ, while the arrangement of the plates in the walls of the lower part of the body, so far as it can be made out from the imperfect specimens that have been collected, seems to connect it with the Crinoideæ. The species is interesting, as it shews us that the organization peculiar to the Blastoideæ,

heretofore not known in rocks of a more ancient date than those of the higher portions of Upper Silurian, made its appearance or existed in the Lower Silurian period.

In order to render the work more useful to the student I have given an introductory section, containing a short account of the history and structure of the Crinoideæ.

E. BILLINGS.

CANADIAN ORGANIC REMAINS.

On the Crinoideæ *of the Lower Silurian Rocks of Canada.* By E. Billings, F.G.S.

SECTION I.

HISTORY AND STRUCTURE OF THE CRINOIDEÆ.

Among the various animal forms that lie entombed in the fossiliferous portion of the earth's crust, none have attracted a greater amount of attention than the Lily Encrinites, or Crinoids,—that group of organic remains to which the following memoir is devoted. Their great abundance in many of the geological formations, the remarkable shapes of the separated fragments of the skeleton, and the peculiar flower-like form of the perfect specimens, must have in all ages excited the curiosity of those whose tastes led them to take an interest in the varied objects of nature; yet it is only within the last century and a half that the first correct ideas concerning their characters began to dawn upon the human understanding. Dr. Mantel informs us that the circular perforated joints of the column occur in the tumuli of the ancient Britons, under such circumstances as to render it quite certain that our forefathers used them for ornamental purposes, and perhaps as objects of veneration in some way connected with the rites of the druidic religion. We have no reason however to believe that they were at that time supposed to be of animal origin. In more recent times they were called, by the peasantry, "fairy-stones," "St. Cuthbert's beads," "screw-stones," or "pulley-stones"; and in Germany, "*Rosenkranzsteine*," rosary-beads;" "*Hunnenthraenen*," giant's tears; or "*Raedersteine*," wheel-stones;—some of these names having been suggested by their form and others originating in the superstitions of earlier ages.

It appears that the earliest publication in which has been found any allusion to the Crinoideæ is a book written in 1558 by Agricola,

the ingenious German miner who taught that petrifactions were not the remains of things which once had an actual existence as living creatures, but simply the shapes of animals generated in the solid rock by some material principle rendered active by the subterranean heat. Entertaining such views, he could not be expected to contribute any important assistance in determining the true characters of fossils which bore no resemblance to any animal then known. From several passages which occur in the writings of this author it seems that, previously to his time, naturalists had given to the different parts of the skeletons of the Crinoids, such as the joints of the stalk or the flower-shaped body, the names of "*Trochites*," "*Entrochus*," and "*Encrinus*," the latter giving origin to the term "Encrinite," afterwards used as a general designation for the whole order. Agricola bestowed the name of *Pentacrinus* upon the bodies of that species now so well known as *Encrinus moniliformis*, applying it not to the whole of the cup, but to specimens which had lost the arms. The separated joints of the pentagonal column, which are somewhat like a five-rayed star, he called *Astroites* or *Asteria*. It is scarcely necessary to add that he did not believe them to be animal remains.

Soon after the time of Agricola the nature of crinoidal remains became a subject of much discussion, and exercised greatly the speculative faculties of a host of writers who were more or less interested in settling the grand problem,— whether or not fossils were of animal origin. For nearly two centuries many of those who placed any confidence whatever in the affirmative of the question still regarded the Crinoids as fossil plants, and contended that the body with its branching arms was the root; others thought that the jointed stalks were the petrified vertebral columns of fishes; while some compared them to the siphuncles of Orthoceratites. It was not until 1719 that one Rosinus published the opinion that the Crinoids were the remains of animals closely allied to the Starfishes, and endeavored to shew that they were provided with a stalk, notwithstanding their animal nature. When it is taken into consideration that at that time no living creature with a structure at all resembling the organism suggested by Rosinus was known, it is clear that such a view must have appeared quite extraordinary to most of the naturalists of the age. A correct theory however often precedes its confirmation, and forty-two years afterwards, or in 1761, a living encrinite, the *Pentacrinus caput-Medusæ*, was drawn up from the bottom of the sea with all its parts constructed exactly in

accordance with the ideas of Rosinus. From the date of this discovery it may be said that the animal origin of the fossil Crinoids was perfectly well established; but no advance was made towards their classification, upon principles deduced from the relations of the different parts of the skeleton, until 1821, when Miller published his work, "The Natural History of the Crinoideæ."*

In this work Miller shews that the calcareous plates which constitute the frame of an encrinite have a quinquepartite arrangement, or consist of five similar sets of plates, which, when spread out in a plane with the base of the cup for a centre, assume the form of a star with five rays. He also pointed out how the genera could be founded upon the various modifications of these rays and upon the number and position of the other plates, such as the sub-radials and inter-radials. Up to the present time scarcely any improvement has been made upon the generic system of Miller. The nomenclature devised by him however for the different plates has been found inconvenient, and others much more useful in application have been substituted. The rules for the construction and determination of genera used by all subsequent authors are essentially those of Miller, and to him, therefore, belongs the credit of having first correctly analyzed the skeleton of the Crinoideæ.

In June, 1835, the famous discovery of Thompson, that, in the young state, the *Comatulæ* so abundant in some of the existing seas are true Crinoids, was communicated to the Royal Society.† In that paper it was shewn that, at certain seasons of the year, the grooves in the pinnulæ of the rays of *Comatula Europæa* are filled with eggs to such an extent that the soft skin which covers the furrow becomes greatly distended, and that shortly afterwards the eggs are discharged and myriads of them distributed about upon sea-weeds, shells, and other marine objects. At first a short, thick stalk, supporting a small, club-shaped head, which exhibits only obscure indications of arms, springs from the deposited egg; but soon the stalk increases in length, the arms are unfolded, and a perfect Crinoid is thus produced from the egg of a *Comatula*. The form and structure so

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* A Natural History of the Crinoidea or Lily-shaped Animals, with observations on the genera *Asteria*, *Euryale*, *Comatula* and *Marsupites*. 4to. 50 colored plates. By J. S. Miller, A.L.S. Bristol, 1821.

† Memoir on the Star-fish of the genus *Comatula*, demonstrative of the *Pentacrinus Europæus*, being the young of our Indigenous Species. By John V. Thompson, F.L.S., Deputy Inspector-General of Hospitals. Communicated by Sir James McGrigor, F.R.S. Edinburgh New Philosophical Journal, volume xx., page 295.

much resembles the large West Indian *Pentacrinus*, that it was for several years thought to be a distinct species of that genus, and was in consequence called *Pentacrinus Europæus*. When further advanced the head, having assumed the form of a *Comatula*, separates from the stalk, and during the remainder of its life moves about through the ocean. As the highly important paper in which this wonderful fact was communicated to the world ought to be in the hands of every student of geology, and as also it is difficult to procure, I have published it entire, with copies of all the original figures, at the end of this Decade.

The next publication in which any great advance in the knowledge of the anatomy of the Crinoideæ was made appeared, in 1841, in the "Transactions of the Royal Academy of Sciences of Berlin." It was a paper entitled, "On the Structure of *Pentacrinus caput-Medusæ*,"* containing the observations made by the late Professor J. Müller while dissecting a specimen which had been captured in the West Indian seas and preserved in spirits. In this memoir Prof. Müller shewed that the grooves which extend from the mouth along the ventral surface to the bases of the arms, and are thence continued upon the arms to their extremities, are true ambulacra, closely allied to those of the Star-fishes. He also greatly improved the nomenclature of the different portions of the skeleton.

In 1854 MM. L. DeKoninck and H. LeHon issued an admirable work, entitled "Researches on the Crinoids of the Carboniferous Formation of Belgium,"† in which these excellent palæontologists give a most able review of the whole subject of the skeleton and classification of these fossils. They have improved the nomenclature, until it is now nearly perfect; and they also devised an ingenious formula, by the use of which all the leading characters of a genus can be expressed by a few words and figures. I shall make an application of this formula to all the Canadian genera. The work besides includes a catalogue giving the title, date of publication and author's name of every book or pamphlet known to contain any description or allusion to the Crinoids from the time of Agricola, in 1558, up to the year 1854. There are upwards of three hundred

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* Uber den Bau des *Pentacrinus caput-Medusæ*. (*Abhandlungen der Koniglichen Academie der Wisenschafften zu Berlin*, 1841, page 177.)

† Recherches sur les Crinoides du Terrain Carbonifère de la Belgique. Par L. DeKoninck et H. LeHon, suivies d'une notice sur le genere *Woodocrinus*. Bruxelles, 1854.

different works noticed; and to collect so great a mass of authority must have cost a vast amount of labor.

The above are the most important works containing information relative to the structure of the Crinoideæ founded upon the personal observations of the authors. The list of books, or periodicals with articles or papers describing new species or genera, is too extensive to be given in this place; and I shall therefore now proceed to notice in detail the different portions of the skeleton of the Crinoids, and to explain the meaning of the technical terms used in the subsequent portion of this memoir.

I. *The Column or Stalk.*

The column usually consists of a long and slender cylindrical stalk, composed of numerous short joints, so closely articulated together, that, during the life of the animal, it must have possessed a very considerable amount of flexibility. It seems probable that in species where the joints are alternately large and small, as in *Glyptocrinus*, there was a greater degree of pliancy than in those instances where it is formed of thin, equally large circular plates, as in the lower part of the appendage in *Rhodocrinus pyriformis*. In the Corniferous limestone smooth round columns one inch in thickness are often found, and these are so firmly constructed, that they must have stood upright, supporting the body of the Crinoid, as upon the top of a pillar. The columns are either pentagonal throughout their whole length, or pentagonal in one part and round in another, or altogether round and smooth. In all the species they are perforated from top to bottom by a small central canal, which is also either circular or pentagonal. This canal no doubt served the purpose of conveying the nourishment from the interior of the body to every part of the column, by which its growth was provided for. In nearly all Crinoids the lower extremity of the column was attached to the bottom of the sea or some other solid object, such as pieces of floating timber, either by a number of branching rootlets, as in *Rhodocrinus pyriformis*, or by a broad, solid base, as in *Cleiocrinus regius*. I think however that certain Lower Silurian species were free, and moved about through the water, dragging their columns after them. I have seen at least a hundred columns of *Glyptocrinus ramulosus* with the lower part preserved, and could never discover any signs of an attachment. In this species the column at the upper end is often half an inch in thickness, and it tapers gradually to half

a line at the lower extremity, a short piece of which, when found perfect, is always closely curled up, like a miniature coil of rope. I think also that sometimes the attached species had their columns broken off by some accident, and that the animal lived long afterwards free, but with a portion still connected with the body. I have seen specimens of *Rhodocrinus pyriformis* with from six to ten inches of the column attached to the base of the cup, with the terminal joint where the fracture occurred rounded, and the alimentary canal closed, or, as it were, healed up. There does not appear to be any way of accounting for this condition of the column, unless upon the above supposition.

The species of the genus *Comatula* now living, all of which are true Crinoids, are attached while young, but free in the adult state. The invaluable observations of Thompson on this genus will, as already stated, be found at the end of this Decade. The *Marsupites* of the Chalk which have no column were also free Crinoids.

II. *Side-arms or Cirri.*

The side-arms or cirri are long, slender-jointed appendages, attached to the column, the purpose of which does not appear to be well understood. They have not yet been found on any of the Lower Silurian species. Some of them are represented in the figures given at the end of this Decade, in the article upon *Comatula.*

III. *The Basal Plates.*

The base of the cup consists of a set of plates arranged in a circle on the top of the column, and in some species where they are large constitutes a saucer-shaped support for the viscera, to the centre of the bottom of which support the column is attached. This part of the skeleton has usually been called the pelvis. In nearly all the Lower Silurian species there are five basal plates; in the Upper Silurian, species with three or four are not uncommon; while in the Devonian those with five plates are comparatively rare.

IV. *The Sub-radial Plates.*

These are always five, and constitute a row resting upon the upper edges of the basals. They occur in the genera *Palæocrinus,*

Dendrocrinus, *Porocrinus*, *Carabocrinus*, *Rhodocrinus*, and others. In *Glyptocrinus*, *Heterocrinus*, *Thysanocrinus*, *Hybocrinus*, and *Cleiocrinus*, there are no sub-radials, the rays springing immediately from the basals.

V. *The Rays and Radial Plates.*

In all Crinoids there are five rays, the lower plates or extremities of which are included in the structure of the cup and form part of the shell, while the upper portions are prolonged above the body, and constitute the arms, which are generally free and more or less branched. In *Rhodocrinus* and *Glyptocrinus* each ray consists at first of a single series of three plates, sometimes called the primary radials or simply the radials; it then divides into two series, called the secondary radials. In these two genera the primary and secondary radials enter into the composition of the cup. In *Glyptocrinus* the first or lowest primary radials rest upon the upper edges of the basal plates, alternating so that each ray is supported by the contiguous sides of two of the basals. In *Rhodocrinus* there is a series of sub-radials between the basals and primary radials. In such genera as *Palæocrinus*, *Carabocrinus*, *Dendrocrinus*, and *Porocrinus*, the first primary radial only is included in the walls of the cup, but the second plate and all above it are free. In the very remarkable genus *Cleiocrinus* the primary, secondary, tertiary, quaternary and quinary rays are all firmly connected together, the free arms commencing with the sixth or seventh division.

The student will find many other modifications of the radial system of the Crinoideæ by consulting the works of various palæontologists; but the above are the more common ones, and those most prevalent in the Lower Silurian of Canada.

VI. *The Inter-radials.*

The divisional space between two rays is called an inter-radius; and as there are five rays, there must be of course an equal number of inter-radii. Four of these are always of equal size, and are called the "regular inter-radii," and when they contain plates these are designated the "regular inter-radials." The fifth is larger than either of the other four, and is called the "azygos inter-radius," from the Greek *azugos*, "unyoked," or "not paired." The plates in this inter-radius are called the azygos inter-radials. In most works the "azygos inter-radials" are termed "anal plates," but as they are

not anal plates, I think another name preferable. The *azygos inter-radials* always mark the anterior side of the animal, or that side towards which the mouth is most approximated. The posterior side is directly opposite, and indicated by the azygos ray. There are thus in every Crinoid two pairs of rays, the right and the left, and an odd or azygos ray. There are also two pairs of inter-radii, the right and left pairs, and an odd one, which is the azygos or anterior inter-radius. When a Crinoid is placed with its anterior side towards the observer, the left anterior ray is opposite his right hand and the right anterior ray opposite his left. Such genera as *Glyptocrinus* and *Rhodocrinus* have both regular and azygos inter-radials, but *Palæocrinus*, *Carabocrinus* and others of a similar structure, have only the latter.

VII. *The Mouth, the Ambulacral Grooves, and Ambulacral Orifices.*

The space on the upper part of the body surrounded by the arms is called the ventral surface, and, by some authors, the vault. It is covered with plates, which are usually smaller than those of the walls of the cup, and disposed without any observable order. The mouth is a circular or oval aperture, situated either in the centre of the vault or between the centre and the margin of the cup, towards the anterior side or below the margin in the side. It sometimes consists of a tube called the "proboscis," which rises from two or three lines to more than an inch above the surface. In some species, such as *Caryocrinus ornatus* (Say), it is closed by a valvular apparatus consisting of five or six small triangular plates. In *Pentacrinus caput-Medusæ* there is a central orifice, and, proceeding from it, five ambulacral grooves on the surface of the vault, which radiate outwards and divide into ten before reaching the margin. The ten grooves proceed straight to the bases of the ten secondary rays or free arms, and are continued upon them to their extremities. The main grooves send out branches to all the divisions of the arms and to each of the pinnulæ. The grooves throughout their whole length are covered over with a soft skin, through which there are numerous minute circular perforations arranged in two rows, one along each side of the groove. These orifices are supposed to be passages for the fluid which serves to extend or retract a set of small sucking feet which are visible on the outside, one over each orifice. The margins of the grooves are bordered by small erect moveable plates, which extend along the

sides like a fence of minute palings. These are the "*marginal plates* of the *ambulacral grooves.*"

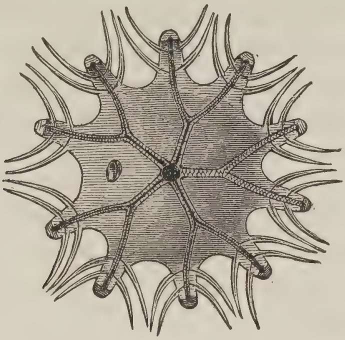

Figure 1.

Figure 1. Diagram of the ventral surface of *Pentacrinus caput-Medusæ*. The central orifice is supposed to be the mouth; the other, the anus. One of the grooves is represented as being closed over by the marginal plates.

The grooves are covered passages, along which are conveyed from the interior of the body to the arms and pinnulæ a number of tubular vessels whose functions appear to be of great importance in the physiology of the Crinoids. As the eggs from which the young are produced are developed in the pinnulæ, no doubt there must be an organ of some kind connected with their generation which communicates with the viscera of the animal by passing along the grooves. Another set of vessels are the aquiferous canals, consisting of long, slender tubes, for the conveyance of the fluid by which the sucking feet of the arms and pinnulæ are extended or retracted. To these must be added the blood-vessels, nervous filaments, and muscles. Traces only of these have been actually observed, but the almost perfect identity in structure between the ambulacra of the Crinoids and those of the Star-fishes, in which it is well known that such organs do exist, renders it quite certain that the former as well as the latter are provided with a full set of ambulacral vessels.

In many of the extinct species of Crinoids, although the arms and pinnulæ are grooved, yet there are no grooves leading from the bases of the arms to the mouth; and it therefore becomes probable that the ambulacral vessels of the arms and pinnulæ do not enter the body through that orifice. Indeed in a great many species, as the mouth is situated in the top of a tube which is sometimes longer than the arms and rises above them, it seems impossible that they

could gain access to the interior by that route. Accordingly a more direct passage is provided. In a great many species which have no calycinal grooves there is an aperture at the base of each arm in which the groove of the arm terminates. I think that in such species the ambulacral vessels, after descending from the extremity of the arms to the bases of the arms, pass directly into the body through these apertures. I have therefore, in Decade III., proposed to call these the "*ambulacral orifices.*"

The genera in which they are most conspicuous are *Actinocrinus*, *Rhodocrinus*, and *Platycrinus*, but there is abundant evidence of their presence in a great many other genera. The subject of these orifices requires a good deal of investigation, as there appear to be many important modifications upon which our Canadian specimens throw no light. In fact all our Lower Silurian species are in such a bad state of preservation, that many years must elapse before the whole of their characters can be worked out. The principal variations in the position of these orifices exhibited by different of the Crinoids, are the following:—

1. Crinoids with the ambulacra continued from the base of the arms over the ventral surface to the mouth—no ambulacral orifices distinct from the mouth,—*Comatula*, *Pentacrinus*, *Palæocrinus*.

2. Crinoids with the ambulacra continued from the bases of the arms to a single ambulacral orifice in or near the centre—the mouth on one side—*Sphærocrinus*, *Crotalocrinus*, *Palæocrinus*, *Carabocrinus*.

3. Crinoids with an ambulacral orifice at the base of each arm, the mouth either central or between the centre and one side.

The following figures exhibit some examples of the variations in the position of the mouth and ambulacral orifices in different species:—

Fig. 2.

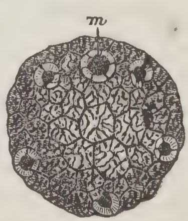

Fig. 3.

Fig. 4.

Figure 2. View of the ventral surface of *Sphærocrinus geometricus* (Goldfuss sp.). *m*, the mouth.

" 3. Ventral surface of *Rhodocrinus verus*. *m*, the mouth.

" 4. *Crotalocrinus*. (From Sir R. I. Murchison's *Siluria*, 1st edition, p. 219.)

In *S. geometricus* the space on the ventral surface surrounded by the arms is proportionally much smaller than it is in most other species. The arms stand in a circle which is one half the diameter of the cup. In the centre of this circular space there appears to have been no large plates. The arms are not placed on the edges of the primary radials, but near the centres of the plates, which have at the point of attachment of the arm in each a small perforation, supposed to be a passage for the brachial muscles. From these points shallow grooves proceed to the open space in the centre. The mouth is situated on one side, between two of the arms, as represented in figure 2, *m*.

In *Rhodocrinus* there are no grooves upon the ventral surface, and the mouth is at one side, between two of the arms (see figure 3, *m*). The ambulacral vessels must therefore have passed directly into the interior through orifices at the bases of the arms.

In *Crotalocrinus* the mouth appears to be central, and provided with an apparatus of small plates by which it could be opened or closed. The ambulacral grooves radiate from it, and divide twice or oftener before reaching the bases of the arms. There must be therefore at least twenty arms, one for each branch of the grooves. The grooves are provided with marginal plates, which are represented in the figure closed down, those of one side of the groove interlocking with those on the other side, and thus forming a roof-like covering over the ambulacral vessels.

SECTION II.

CRINOIDEÆ OF THE CHAZY LIMESTONE.

The lower part of the Chazy group consists of sandstones, shales, and impure calcareous rocks, and the upper part of limestone, in general thick-bedded and densely crowded with organic remains. Some of the strata of this limestone are composed almost entirely of *Rhynconella plena*, others of several undescribed species of *Orthis*, while many of them are little else than compact masses of the comminuted remains of Cystideans and Crinoids.

There are at the present time known to be eleven species of Crinoids in this formation, and of these five will be characterized in the following pages; but of the other six we have as yet only the columns and some of the detached plates. Although we cannot determine the genera of these six species, yet it is quite certain that they are different, not only from those hereinafter described, but also from each other. None of the species are clearly identical with any that occur in either the Black River or the Trenton limestones, although one, *Hybocrinus pristinus*, is closely allied to *H. tumidus*, and may perhaps be a variety thereof.

The Crinoids and Cystideans of the Chazy appear to have been confined to a comparatively small area of the Silurian ocean. The grey limestone in which they occur is exposed in numerous localities on the islands of Montreal, Jesus, and Bizard, and in that tract of Silurian country which lies between the Ottawa and St. Lawrence rivers. It also extends from the island of Montreal southerly to the neighbourhood of Lake Champlain, and is largely exposed at the village of Chazy, the typical locality of the formation. This part of the formation has not been identified west of Kingston, nor so far east as Three Rivers. It lies therefore altogether within an area of about two hundred miles in length by one hundred in breadth. Outside of this area none of the Chazy Crinoids or Cystideans have been discovered.

Although for practical purposes it is most useful to treat of the Chazy as a formation distinct from that of the Birdseye and Black River limestone, yet the two deposits are most closely connected zoologically, since we find that, out of seventy-five species, about twenty, or more than one fourth, are common to both.

Blastoidocrinus carchariædens, Billings.

Plate I. Figures 1*a*, 1*n*.

Description.—Although the remains of the somewhat extraordinary species for which the above name is proposed are exceedingly abundant in the Chazy Limestone, and have for a long time attracted the attention of geologists, yet no specimens have been collected sufficiently perfect to enable us to make out the arrangement of all the parts. Indeed, so remarkable is the form of the principal plates, and so unlike any other fossils known in the Lower Silurian rocks, that, until very recently, no one has succeeded in shewing how they

could be brought together at all in such a manner as to constitute an organic structure. By several fortunate discoveries, however, of fragments of the body, with some of the plates still occupying their natural position, we are now in possession of data by which the more important details can be demonstrated, and no doubt other specimens will in course of time be found to supply the remainder.

The remains of this species most usually occur in an extremely comminuted state, and in such abundance that in many localities they constitute almost the whole of the ingredients of beds of solid rocks, of from six inches to three feet in thickness. Very frequently, where the rock has been long exposed to the action of the atmosphere, the large unbroken plates are weathered out and displayed in strong relief upon the surfaces of the strata; and as they are easily recognized and strictly characteristic of the Chazy limestone, they constitute a most valuable and safe guide to the explorer in tracing out the distribution of the formation, or in determining the age of isolated patches where other fossils may be absent, or where the test of superposition cannot be made available.

The form of these large plates is nearly triangular, two of the sides being straight or gently curved outwards, and the third more or less strongly arched inwards. This last mentioned side, when the plate is in its natural position in the perfect cup, is the lower side, and the angle immediately opposite to it the apex. The plates are not flat, but have a concavity extending from the apex downwards, being the deepest at the base, thus giving a form somewhat like that of an ordinary shoe-lifter. The length of the base measured in a straight line between the two lower angles, and, without following the curvature, is, in a specimen of the average size, about ten lines; the length of the other two sides, when compared with the base, is either equal to it or a little greater. The surface is ornamented with fine straight parallel striæ, from six to ten in the width of a line, and running in a direction from the base upwards. When the specimens are a little worn these striæ are obliterated, and the surface is then smooth or granular. The concave side of the plate is the outer side.

The specimen represented by figures 1*i*, 1*k* and 1*l*, Plate I., shews that the upper or ventral surface of the perfect fossil is divided into five equal portions by five rays or pseudambulacra, which radiate from the centre outwards, and that the place of the triangular plates above described is in the angles between the rays. There are thus five of these plates in the skeleton of each individual. The rays consist of two rows of narrow, elongated plates, placed transversely,

and which appear to be the homologues of the ambulacral plates of the rays in the genus *Pentremites*. The width of the rays near the centre is two lines, and there are four of the small transverse or ambulacral ossicula in the length of one line. The specimen does not shew the centre of the ventral surface, so that we cannot determine whether the mouth was situated there or not. In order to exhibit the analogy or affinity between this genus and *Pentremites*, I have had the following figures prepared :—

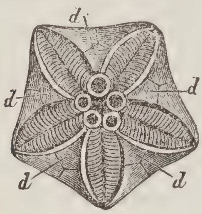

Fig. 5.

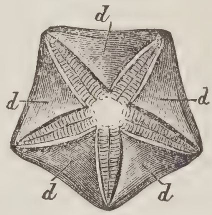

Fig. 6.

Figure 5. The ventral surface of *Pentremites pyriformis* (Say). *d*, the deltoid plates, extending only half the length of the pseudambulacra.

" 6. The ventral surface of *Blastoidocrinus carchariædens*. *d*, the deltoid plates, extending the whole length of the pseudambulacra. The unshaded space in the centre is most probably the place of the mouth.

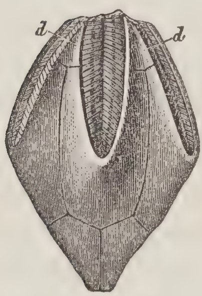

Fig. 7.

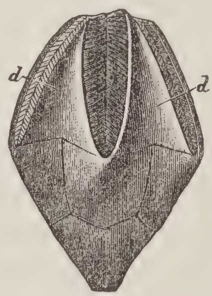

Fig. 8.

Figure 7. Side view of *P. pyriformis*.

" 8. The same, but with the deltoid plates extended to the extremities of the pseudambulacra, as in *B. carchariædens*.

From the above figures it appears quite probable that the large triangular plates of this species are the exact homologues of the deltoid plates of the *Pentremites*. If we imagine a pentremite with its deltoids so greatly developed that they would occupy the whole

of the spaces between the pseudambulacra, the structure would be exactly that of the upper surface of *Blastoidocrinus*.

From another specimen it appears that there are at least three, if not four or five, basal plates, and their form is remarkable, as they do not rest upon the upper surface of the upper joint of the column, as in the ordinary Crinoids, but have their inner edges turned upwards into the body of the cup, leaving a circular aperture in the bottom through which the column actually penetrates into the interior, nearly if not quite to the top of the visceral cavity. This is so extraordinary a structure that scarcely any palæontologist at all well acquainted with the organization of the Crinoideæ could be brought to believe it without personal inspection of the proofs. The two specimens in which the evidence is exhibited were discovered in two different localities. That represented by figures 1*i*, 1*k* and 1*l*, I found in a wall about half a mile west of the village of St. Laurent, on the island of Montreal; the other, figure 1*m*, in a quarry five or six miles east of the village. It is quite clear that they are not portions of the same individual. The St. Laurent specimen is part of an individual split in two from top to bottom, and exposing the interior exactly where the column should be found, if it penetrate through the base to the upper part of the visceral cavity, as above supposed. Such is its position in the specimen, as shewn in figure 1*l*. I at first thought that this might be the result of some accident; but having soon afterwards found the specimen represented by figures 1*m* and 1*n*, where a piece of the column is seen penetrating through the base, I believe it to be the natural arrangement. The column is round, with an alimentary canal so small that often the detached joints seem to have no central perforation. I have seen it however distinctly in a great many specimens. The flat faces of the separate joints exhibit strong radiating striæ. Thickness of column, two lines; and of the joints, from one fourth to half a line.

We often find associated with the remains of *B. carchariædens* some small fossils which appear to be the joints of a pentagonal crinoidal column. I have represented several of these by figures 1*o*, 1*p*, 1*s*, plate 1. They have five concave sides, and usually one end is rounded (see figure 1*s*), and the other generally flat, with five deep grooves radiating from the centre to the angles. In some specimens both ends are rounded; in many there is no central perforation, but in others there is. These are certainly crinoidal remains, but we have no means of shewing to what species or genus they belong.

EXPLANATION OF FIGURES. PLATE I.

Figures 1*a*–1*h*. Deltoid plates of *B. carchariædens*.
" 1*i*. Side view of a specimen which has three of the rays partly preserved.
" 1*k*. The same, seen from above.
" 1*l*. Vertical section, shewing the position of the column in the interior.
" 1*m*. Fragment of the base, shewing the manner in which the column penetrates into the visceral cavity.
" 1*n*. Under side of 1*m*.
" 1*o*–1*s*. Small pentagonal crinoidal remains found associated with *B. carchariædens*.

Locality and formation.— Caughnawaga, Island of Montreal, Isle Jesus, Isle Bizard. Chazy limestone.

PACHYOCRINUS CRASSIBASALIS, Billings.

Plate I. Figures 3*a*, 3*b*.

Description.—Of the species for which the above name is proposed no perfect specimen has been found, and yet we have sufficient to shew that it belongs to a new genus. There are five small pentagonal basal plates concealed within the cavity for the attachment of the column. Above these and alternating with them are five very large and thick plates, which may be either sub-radials or first-radials. The lower portions of these plates are curved under the body, so as to constitute a broad, rounded or concave bottom to the cup, which has a width of nine lines at a height of about two lines. At this level the cup is broken off in the only specimen discovered, and we have no means of determining what was the structure above. There are no other Crinoids in the Lower Silurian rocks with a base like this, for although in the genus *Rhodocrinus* some of the species have a concave bottom, yet the sub-radial plates are always small and thin. It is true that mere difference in the size of organs or portions of an organic structure is not always of generic value; yet, where it is so extremely great as it is between the sub-radials of *Rhodocrinus* and the second series of this species, it is generally found that other differences exist sufficient to warrant a separation of the species in which such differences occur into distinct genera. I am inclined to believe, therefore, that when perfect specimens are found they will shew that this is a new genus.

EXPLANATION OF FIGURES. PLATE I.

Figure 3*a*. View of the base of the specimen.
" 3*b*. Side view of the same.

Locality and formation.—Two miles north of Montreal, in the Chazy limestone.

Genus Hybocrinus, Billings.

(Hybocrinus, *Report Geological Survey of Canada*, 1856, page 274.)

Formula :

Basal plates, 5.	Azygos inter-radials, 2.
Radial plates, 1×5.	Regular inter-radials, 0.

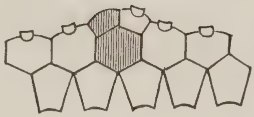

Figure 9.

Figure 9. Diagram of the structure of the cup of the genus *Hybocrinus.*

Generic characters.—Cup, globular or pyriform, more protuberant upon one side than on the other, composed of five basal, five radial, and two azygos plates. The five basal plates are pentagonal, and alternating above them is a row consisting of one large azygos plate and four of the radials. The large azygos plate supports upon its upper right-hand sloping edge the second small azygos, and on the left the fifth radial. The arms in all the species that have yet been discovered are undivided, and each is composed of a single series of joints. The column is round and short. The generic name is derived from the Greek *hubos* (bent outwards or hump-backed).

Hybocrinus pristinus, Billings.

Plate I. Figure 2*a*.

Description.—This little species is usually about three lines in height and four lines in width, measured across the cup from the posterior to the anterior side. The anterior side is very protuberant, and the plates, although they appear smooth to the naked eye, yet, when a little magnified, are seen to be covered with small irregular tubercles. The arms are single and somewhat narrowly rounded on the back, the joints about one line in length. The column is round, half a line in thickness, and composed of joints which are, as far as

Note.—In the expression radial plates, 1×5, the figure 1 indicates the number of plates in each primary ray, and the figure 5 the number of rays. In the diagram the shaded plates are the azygos inter-radials.

known, of an uniform size, there being on an average about ten in the length of two lines.

This species so closely resembles *H. tumidus* of the Trenton limestone, that I have had much doubt as to the propriety of separating it therefrom. The only differences that I can perceive are, that it is always smaller than the Trenton form, the plates more coarsely granulated under the lens, and not so convex in their centres. The column does not taper so rapidly, and it is composed of joints which are thicker in proportion. In a well-preserved specimen of *H. tumidus* the column exhibits from eight to ten joints in the length of one line, whereas in *H. pristinus* there are only five. Under these circumstances I have thought it best to distinguish the Chazy specimens by a separate name for the present.

Locality and formation.—Detached plates are rather common in the Chazy limestone at Caughnawaga, and at various localities on the Islands of Montreal, Jesus and Bizard; also in the front part of the Township of Hawkesbury. Perfect specimens are rare.

Genus PALÆOCRINUS, Billings.

FORMULA:

Basal plates, 5.	Azygos inter-radials, 1–3.
Sub-radial plates, 5.	Regular inter-radials, 0.
Radial plates, 1×5.	Calycinal ambulacra, 5.

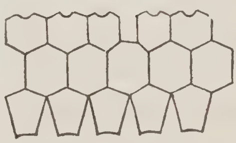

Figure 10.

Figure 10. Diagram of the cup of the genus *Palæocrinus*. The azygos inter-radial space is left blank in the figure, as it is not certain how many plates it contains.

Generic characters.—Cup, oval or pyriform, composed of five pentagonal basal plates, alternating above which are four hexagonal and one heptagonal sub-radial plates, and above these five radials bearing the free arms. The heptagonal sub-radial supports upon its truncated summit one, two, or three small azygos inter-radials. The rays are slender, and free from the second joint inclusive. There are five calycinal ambulacral grooves radiating from the centre of the abdominal surface to the bases of the arms, where there appear to be

also five small orifices leading to the interior. The mouth is probably situated near the margin, at the azygos inter-radius. Column, either round or pentagonal.

This genus belongs to that group of the Crinoideæ which includes such genera as *Cyathocrinus*, *Poteriocrinus*, *Dendrocrinus* and *Porocrinus*, to all of which it is closely allied in structure, but differs in the presence of calycinal ambulacral furrows.

PALÆOCRINUS STRIATUS, Billings.

Plate I. Figures *5a*, *5b*.

Description.—Cup, oval, gradually expanding from a small base to the width of five lines at the margin of a specimen seven lines high. The plates are depressed convex, and have a small round tubercle in the centre. They are also beautifully ornamented with radiating striæ or somewhat sharp, elevated ridges. One of these extends from the centre of each plate to the middle of each edge, and, crossing the suture at right angles, proceeds straight to the centre of the contiguous plate. Parallel with these principal ridges are four or five other shorter ones, also crossing the suture at right angles. Those nearest the principal ridge are the longest, and the length gradually decreases towards the angles. Where the ridges cross the suture, there are from three to five of them in the width of one line.

The only specimen collected shews very distinctly two ambulacral orifices at the bases of two of the arms, and two calycinal ambulacra leading therefrom towards the centre. The other three grooves are indistinctly indicated, but sufficient appears to leave little doubt as to their existence. The arms and column are unknown.

The plates of this species so closely resemble those of the cystidean *Palæocystites tenuistriatus*, that they can only be distinguished after much practice. The striæ on the surface of the latter species are always a little finer and of a nearly uniform size.

EXPLANATION OF FIGURES. PLATE I.

Figure *5a*. Posterior side of a nearly perfect specimen.
" *5b*. Summit of the same, shewing the ambulacral orifices and grooves.

Locality and formation.—Somewhat common in the Chazy limestone at Caughnawaga and on the Island of Montreal.

Genus RHODOCRINUS, Miller.

(RHODOCRINUS, Miller, 1821. *Natural History of the Crinoideæ*, page 106.)

(GILBERTSOCRINUS, Phillips, 1836. *Geology of Yorkshire*, vol. ii., page 207.)

(THYSANOCRINUS, Hall, 1852. *Palæontology of New York*, vol. ii., p. 186.)

FORMULA :

Basal plates, 5.	Regular inter-radials, 6 to 8×4.
Sub-radial plates, 5.	Azygos inter-radials, 7 to 12.
Radial plates, 3×5.	

Figure 11.

Figure 11. Diagram of the structure of the cup in the genus *Rhodocrinus*.

Generic characters.—Cup, globular or oval; arms, long, often much branched, and densely fringed with pinnulæ; basal plates, five, alternating above which are five sub-radials; primary rays, five, consisting of three plates each; secondary rays, ten, the number of plates in each varying from one to four. The number of regular inter-radials varies from six to eight, while the azygos inter-radials are more numerous. The free arms spring from the secondary radials. In all the Canadian species the column is round, strongly annulated in the upper portion, and smooth below. The radix or base of attachment consists of a number of small, branching roots. The ambulacral orifices are situated at the bases of the arms, and the mouth, in all the species in which it has been observed. is excentric.

In the "Natural History of the Crinoideæ" Miller described this genus as having only three basal plates, an error into which it was easy for him to fall, on account of the minuteness of these plates in most of the species. In consequence of this mistake, several other genera were founded on specimens with five basal plates; but as it has been ascertained that Miller's original specimens have also five, these genera cannot be retained.

In the Report of the Geological Survey of Canada I referred with doubt two of our species, *R. pyriformis* and *R. microbasalis*, to the genus *Thysanocrinus* of Hall. They are very clearly congeneric with the *Thysanocrinus liliformis* of the Niagara limestone, while they have also in general the same structure as *Rhodocrinus*. There are however some differences in the form of the body and the upper parts which led me to think the genera might be distinct; but not being decided, I referred them to *Thysanocrinus*, at the same time giving the other name in a parenthesis. During the last summer I discovered the small species, *R. asperatus*, which has not only the structure but the aspect also of the typical forms of *Rhodocrinus*, and I think therefore that our three species should be placed in that genus.

Rhodocrinus asperatus, Billings.

Plate I. Figures 4*a*–4*e*.

Description.—Cup, small, nearly globular; surface covered with numerous small, conical, irregular tubercles. The basal plates are so exceedingly diminutive as to be entirely concealed within the cavity in the centre of the base in which the column is inserted. The column is round, and strongly and closely annulated near the base with very thin, sharp, projecting joints or rings, as in the other species of this genus. Judging from some fragments found associated with the specimen figured, it would appear that the arms are long and thickly fringed with well-developed pinnulæ. Height of cup in the only specimen discovered, six lines; diameter, the same.

Explanation of Figures. Plate I.

Figure 4*a*. Side view of the specimen.
" 4*b*. View of the base.
" 4*c*. A radix found in the same slab along with 4*a*.
" 4*d*. Portion of the surface of 4*c* magnified. The joints of this column appear to be composed near the root of five pieces each, which interlock, as represented in the figure 4*d*.
" 4*e*. Transverse section of the column near the root.

Locality and formation.—This species occurs in the Chazy limestone, in a quarry about two miles north of the City of Montreal. Exceedingly rare.

SECTION III.

CRINOIDEÆ OF THE TRENTON LIMESTONE AND HUDSON RIVER GROUP.

Although in almost every exposure of the Trenton limestone we find remains of the Crinoideæ, yet in general they consist of mere fragments, such as joints of the column or the detached plates of the cup. At the city of Ottawa they are found in a better state of preservation, but seldom perfect. Nearly all the species that we have been able to determine were collected at that locality; and as we know, from the researches of geologists in other countries, that these fossils are often confined to limited areas, it appears probable that few of ours will be found elsewhere.

The Hudson River species are so closely allied to the Trenton that I have not thought it necessary to describe them in a separate section.

Hybocrinus tumidus, Billings.

Plate II. Figures 1*a*–1*e*.

(H. tumidus, *Report Geological Survey of Canada*, 1856, page 275.)

Description.—Smaller than *H. conicus;* sub-globular, the plates tumid in their centres; column, slender and round, composed of thin joints, and tapering towards the base; surface of the plates, obscurely granular; length of cup, six lines; breadth at margin, about eight lines; arms, one line broad upon the back, composed of joints one line in length. Although about twenty heads of this species have been collected, none of them are quite perfect. They all are smaller and of a different form from *H. conicus.*

The ambulacral orifices in this species are indicated by a strong, narrow, rounded channel in the centre of the upper edges of the primary radial plates.

EXPLANATION OF FIGURES. PLATE II.

Figure 4*a*. View of the anterior side of a specimen, shewing the azygos plates.
" 1*b*–1*d*. Different views of other specimens.
" 1*e*. A polished transverse section just below the base of the arms, shewing the channels in the primary radial plates for the ambulacral orifices.

Locality and formation.—Trenton limestone; City of Ottawa.

HYBOCRINUS CONICUS, Billings.

Plate II. Figures 2*a*–2*b*.

(H. CONICUS, *Report Geological Survey of Canada*, 1856, page 274.)

Description.—In this species the cup is conical, with slightly ventricose sides; the base narrow, and the arms long and undivided; plates, smooth; height of cup, thirteen lines from the base on the azygos side to the upper margin; height of the opposite side, nine lines; length of the arms, three inches; the basal plates occupy more than one half the height on the azygos side and about one half on the others; the arms are one line and a half in width, broadly rounded on the back, and composed of a single series of joints, each one line in length; on their insides the ambulacral grooves are margined by rows of small plates resembling those upon the arms of some of the Cystideæ (*Pleurocystites*); about five of those plates to one joint of the arm. The column is round and smooth, consisting of very thin joints, ten to one line. The mode of attachment to the bottom was by a broad button-shaped base. Length of column in the largest specimen seen, one and three-quarter inches.

EXPLANATION OF FIGURES. PLATE II.

Figure 2*a*. Right side of a specimen of the average size.
" 2*b*. Left side of another specimen.

Locality and formation.—Trenton limestone, City of Ottawa.

Genus CARABOCRINUS, Billings.

(CARABOCRINUS, *Report Geological Survey of Canada*, 1856, page 275.)

FORMULA:

Basal plates, 5.	Regular inter-radials, 0.
Sub-radial plates, 5.	Azygos inter-radials, 3.
Radial plates, 1×5.	

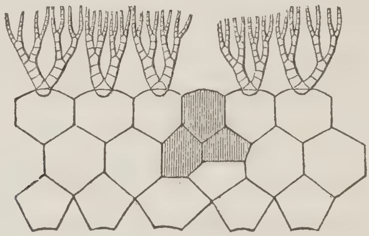

Fig. 12.

Figure 12. Diagram of the structure of the cup in the genus *Carabocrinus*.

Generic characters.—Cup, globular or ovoid; basal plates, five, four of them pentagonal, and the fifth hexagonal; sub-radials, five, three of them hexagonal, one heptagonal, and one pentagonal, the latter smaller than the others; primary radials, five, each bearing an arm which is several times divided. The azygos inter-radius is rather large, and occupied by three plates. One of them is supported upon the hexagonal basal plate; a second upon the small pentagonal sub-radial; the third is situated between the two anterior primary radials, its upper edge forming the margin of the cup, and its two lower sides resting upon two of the upper sloping sides of the first and second azygos plates.

Upon the ventral surface five calycinal ambulacral grooves radiate from the centre (where there appears to be an aperture) to the bases of the arms; the mouth is situated in the margin over the azygos plates; there is a small aperture, surrounded by an elevated border, half-way between the mouth and the centre. I think this small orifice is the anal aperture.

This genus is distinguished from the genera *Cyathocrinus* and *Poteriocrinus* by the depth to which the azygos inter-radials descend. In these two genera they are always situated above the sub-radials; but in *Carabocrinus* one of them stands upon one of the basal plates. The generic name is from the Greek *karabos*, a crab.

Carabocrinus radiatus, Billings.

Plate II. Figures 3*a*–3*e*.

(C. radiatus, *Report Geological Survey of Canada*, 1856, page 276.)

Description.—Cup, globose, rather broader at the margin than it is high; base, broadly rounded; surface, covered with strong rounded ridges, which radiate from the centres of the plates; arms, short, three times divided; column, round and slender, composed of alternately projecting thin joints. From the centre of each sub-radial plate two principal ridges ascend diagonally to the bases of the two arms on both sides; two others radiate to the centres of the two sub-radials on either side; and thus a series of triangles is formed round the upper half of the cup. In a similar manner ridges extend from the centres of the sub-radials to the centres of the basal plates, thus constituting another set of triangles in the lower half. Within each triangle, both in the upper and lower halves, are contained two or three smaller triangles, one within the other. In consequence of this arrangement, the ridges appear to radiate in groups of three or four.

Each arm-plate supports in its centre a small but stout pentagonal second radial plate, from the upper sloping edges of which spring two short round arms, which divide again at the second joint; these branches are again divided once or twice above. Height of the largest specimen, one inch; diameter at half the height, fourteen lines. Specimens are in the collection of all sizes, from three lines to twelve in diameter.

Explanation of Figures. Plate II.

Figure 3*a*. View of the anterior side, shewing the azygos inter-radius.
" 3*b*. Base of the same specimen.
" 3*c*. Posterior side of a different specimen.
" 3*d*. Ventral surface of a small individual. In the centre of the lower side of the figure is the mouth, and directly above it the small anal aperture.
" 3*e*. Ventral surface of a larger specimen, shewing obscurely the five ambulacral grooves. The three round darkly-shaded spots appear to be apertures accidentally produced.

For the fine specimen represented by figures 3*a* and 3*b*, we are indebted to Mr. Charles Wright, of Hull, Ottawa.

Locality and formation.—Trenton limestone; City of Ottawa.

Carabocrinus Vancortlandti, Billings.

Plate II. Figure 4.

Description.—Of this fine and rare species only one specimen has been seen, and that is unfortunately so much injured on the anterior side that the arrangement of the azygos plates cannot be determined. The form of the body is rather broad oval, the height being fifteen lines from the base to the margin, while the greatest diameter near the centre of the body is twelve lines. The base is narrowly rounded, and the cup expands gradually for about half the height, above which it contracts to the margin, where the width is about one line less than it is at the centre. The height of the posterior basal plate is five lines and a half, its greatest width four lines; the hexagonal basal, five lines high and about the same in width. Of the sub-radials, three are well-preserved; they are slightly narrower below than above. Height of the sub-radials, eight lines; width between the two upper lateral angles, seven lines, and between the two lower, five lines. The primary radials are each six and a half lines wide and five lines high. The arms are rounded on the back, and a little more than one line in thickness. They have each three single joints, the third being pentagonal and supporting upon its upper sloping sides two secondary rays, which are subdivided at the distance of two lines and a half.

The surface is ornamented with radiating ridges, as in *C. radiatus;* but the ridges are proportionally smaller and more distant from each other.

This species is clearly distinct from *C. radiatus*, from which it differs in being of an oval instead of a subglobular shape. In all the specimens of *C. radiatus* the width is greater than the height; while in *C. Vancortlandti* the height is greater than the width. It is also to be observed, that in the former the arms divide above the second free joint, and in the latter above the third.

The species is dedicated to Dr. E. Vancortlandt, of the City of Ottawa, whose zeal in the advancement of science has been productive of many beneficial results. The only specimen known belongs to his cabinet, and has been kindly communicated by him to us for description.

Explanation of Figures. Plate II.

Figure 4 exhibits a view of the posterior side of the specimen.

Locality and formation.—Trenton limestone; Township of McNab, near Arnprior.

Carabocrinus? tuberculatus, Billings.

Plate X. Figures 2*a*, 2*b*, 2*c*.

Description.—Cup, sub-globular or broadly oval; surface of plates covered with small, rounded tubercles; arms, large, long, several times divided; column, round, and in the upper part composed of alternately thick and thin joints.

Of this species we have only one specimen, and that is imperfect. The distinctive characters are the tuberculated surface and large arms. Although I have not seen the azygos inter-radials, yet the general aspect of the specimen is so much like that of *Carabocrinus*, that I have little doubt it belongs to that genus.

Explanation of Figures. Plate X.

Figure 2*a*. The only specimen collected.
" 2*b*. Three joints of the column, enlarged.
" 2*c*. One of the joints of the arms, enlarged.

Locality and formation.—Hudson River group, Charleton Point, Anticosti.

Genus Porocrinus, Billings.

(Porocrinus, *Report Geological Survey of Canada*, 1856, page 279.)

Formula :

Basal plates, 5.	Regular inter-radials, 0.
Sub-radials, 5.	Azygos inter-radials, 2.
Radials, 1 × 5.	

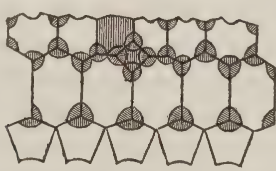

Figure 13.

Figure 13. Diagram of the structure of the cup in the genus *Porocrinus*.

Generic characters.—Cup, conical; basal plates, five, pentagonal; sub-radials, five, three hexagonal and two heptagonal; primary radials, five; one large azygos inter-radial, supported on the truncated summit of the anterior sub-radial, and one small one, situated

over the suture between the anterior and left anterior sub-radials, and having above it on one side the large azygos, and on the other the left anterior primary radial; several small pectinated rhombs, similar to those of the Cystideæ.

The characters of this genus are nearly the same as those of *Cyathocrinus*, *Poteriocrinus* etc., but differs from these and other allied genera in the presence of the pectinated rhombs. Only one species is known.

Porocrinus conicus, Billings.

Plate II. Figure *5a–5d*.

(P. conicus, *Report Geological Survey of Canada*, 1856, page 279.)

Description.—Cup, one line and a half in diameter at the base and gradually enlarging, with slightly ventricose sides, to the width of five lines at the margin; height, seven lines; basal plates narrow, nearly two lines high; sub-radials, three lines in height; first primary radials, about two lines and a half in height and breadth; all the plates smooth; column, circular, smooth, and suddenly enlarged near and up to the base of cup, composed of very thin joints; free rays, long, slender and single to their extremities; they are about half a line in thickness, and appear to be composed of a single series of joints. Only about one inch in length of the column next the base has been seen.

In this species there exists a number of poriferous areas resembling the pectinated rhombs of the Cystideæ in their structure, and probably adapted to the performance of the same functions. Their forms and position are however somewhat different from those of any known cystidean. In fossils of the latter order these organs consist of two parts, one situated upon each of two contiguous plates, but in this crinoid, each is so placed that it occupies the angles of three plates. Their form is that of an equilateral spherical triangle, and their size about one line in diameter. There are five situated at the apices of the five basal plates, five at the lower angles of the arm-plates, five at the apices of the sub-radials and five between the arm-plates on the margin of the cup. There are also two or three small ones at the angles of the azygos-plates, in all twenty-two or twenty-three. The pores consist of fine elongated parallel slits, which appear to penetrate through the plates; they are not at right angles to the margin of the plates as in the Cystideæ, but oblique.

The central pore of each division divides the angle into two equal portions, and all the other pores upon the plate are parallel to this central one ; consequently in each area they have three directions in which they are at right angles to the sides of the triangular space in which they are situated, but oblique with respect to the margins of the plates.

EXPLANATION OF FIGURES. PLATE II.

Figures 5*a*, 5*b*. Posterior views of two specimens.
" 5*c*. Anterior side of a specimen, enlarged to shew the azygos plates and poriferous areas.
" 5*d*. Ventral surface of 5*a*.

Locality and formation.—Trenton limestone, City of Ottawa.

Genus DENDROCRINUS, Hall.

(DENDROCRINUS, Hall, *Palæontology of New York*, volume ii., page 193.)

FORMULA:

Basal plates, 5.	Regular inter-radials, 0.
Sub-radials, 5.	Azygos inter-radials, 1.
Radials, $1 \times 4 + 1 \times 2 = 6$.	

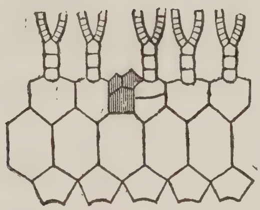

Fig. 14.

Figure 14. Diagram of the structure of the cup in the genus *Dendrocrinus*.

Generic characters.—In this genus there are five pentagonal basal plates, and alternating above these a series of five sub-radials, one of which has its superior angle truncated, and supports a large azygos inter-radial. There are five rays alternating above the sub-radials ; the ray on the left-hand side of the large azygos inter-radial has two of its plates entering into the composition of the cup ; this ray is free, from the third joint inclusive ; of the other four rays, only the first joint is included in the cup. A large and long proboscis rises from the azygos inter-radial plate.

This genus is exactly the same in the composition of the test as *Cyathocrinus* with the exception of the peculiarity that one of the rays has two of its joints contained in the walls of the cup. In the original description given by Professor Hall, (Pal. N. Y., vol. 2, p. 193,) four series of plates are mentioned, including five "scarcely visible" plates beneath those which I regard as constituting the true base; they cannot be seen in any of the specimens in the collection of the Survey, although at least four of the species are unquestionable congeneric with *D. longidactylus* (Hall).

I have seen Professor Hall's specimens, and he agrees with me that the generic description may be so modified as to receive many species with the same structure in other respects, but which do not exhibit the small plates at the base. It will be seen by referring to fig. 7, c, plate 42, vol. 2 Pal. of New York, that the column of *D. longidactylus* consists of alternately large and small (or thin) joints, and that the latter sometimes consist of five divisions. Professor Hall is now of opinion that the small pieces at first regarded as constituting the true base are not of generic importance, and that they may be considered either as one of the quinquepartate thin plates of the column, or as a basal series so little developed as not to be of more than specific value.

It will be recollected by those who have studied the Crinoideæ, that a similar question relating to the base of *Poteriocrinus* still remains unsettled; Professor Philips and the Messrs. Austin having published that genus with three minute plates situated under the three basal plates.

Dendrocrinus gregarius, Billings.

Plate III. Figures 1*a*, 1*b*, 1*c*.

(D. gregarius, *Report Geological Survey of Canada*, 1856, page 265.)

Description.—Cup, acutely conical, from three to eight lines in length, and from two to six lines broad at the greatest diameter, which is at the margin, whence to the small pointed base it tapers uniformly with nearly straight sides; basal plates, narrow, nearly one third the height of the cup; sub-radials, rather more than one third broader than high; large azygos inter-radial, not quite so large as the plate on which it stands, broader above than below; proboscis,

for several lines above the azygos, nearly as wide as the cup, and composed of numerous small plates, which appear to be regularly arranged in upright rows; the arms bifurcate once immediatly after becoming free, and many times again above; they are very long and obtusely angular on the back. Below the first bifurcation there are about four joints, and they occupy a length of two lines in a specimen where the cup is six lines high and the arms two inches and one-fourth long. Their thickness in this part is about half the width of the first primary radial plates from which they spring, and they appear to hold a very deep groove on their inside, as the thickness is greater in that direction than it is in the other; the column is round, slender and flexible, slightly enlarging near and up to the base of the cup, and composed of alternately thick and thin joints, about six of each in a line of the length; the plates are without ornament.

This species so much resembles *D. longidactylus* (Hall) of the Niagara group that it can scarcely be separated. The principal differences consist in its smaller dimensions, and in the absence of the vertical ridges along the proboscis. On comparing with the illustrations given in the Palæontology of New York, it will be seen that the second plates of the rays on each side of the proboscis are in fig. 1*a*, plate 43, broader than those upon which they rest. In our specimens the second plate of the left-hand ray is equal to the first; in the right-hand ray it is a great deal less, agreeing in this respect with fig. 7*a*, plate 42. The species are closely related, and yet I am satisfied they are different.

Explanation of Figures. Plate III.

Figure 1*a*. Posterior view of a specimen.
" 1*b*. The left side.
" 1*c*. Column, enlarged.

Locality and formation.—City of Ottawa, in the central part of the Trenton limestone.

Dendrocrinus acutidactylus, Billings.

Plate III. Figures 2*a*, 2*b*.

(*Report Geological Survey of Canada*, 1856, page 266.)

Description.—Cup, small, conical somewhat pentagonal; arms, very slender, several times sub-divided and excessively sharp on the back; column, round, composed of small nearly globular joints;

length of cup in the specimen examined, two lines, breadth at base of free rays, the same; length of free rays, one inch and one-eighth; thickness upon the back below the first sub-division, about one-fifth of a line. At three-fourths of an inch below the base of the cup there are five joints of the column to one line in length. The two arms visible in the specimens bifurcate at the fourth free joint, and three times again at varying distances above. Only one side of the specimen can be seen, yet the characters of the cup and arms are so similar to those of the last species that there can be little doubt of its generic affinities while the globular joints of the column and the thin sharp backed arms are characters sufficient to separate them specifically.

EXPLANATION OF FIGURES. PLATE III.

Figure 2*a*. Posterior side of a specimen.
" 2*b*. Portion of the column, enlarged.

Locality and formation.—Upper part of the Trenton limestone, near the Toll-gate, St. Lawrence Street, Montreal.

DENDROCRINUS PROBOSCIDIATUS, Billings.

Plate III. Figures 3*a*, 3*b*, 3*c*.

(D. PROBOSCIDIATUS, *Report Geological Survey of Canada*, 1856, page 267.)

Description.— Cup, small, conical sub-pentagonal; proboscis, enormously large in proportion to the size of the cup; column, pentagonal with raised edges along the five angles, and with concave faces between, composed of very thin joints, twenty-four in the length of two lines; the arms are thin and sharp on the back. In a specimen, the crushed cup of which is three lines in length, there is a proboscis attached, sixteen lines in length; the portion seen is of a very remarkable structure; it is composed of four vertical rows of small plates, with a strong central keel running up each row, from either side of which projects, nearly at right angles, a pair of short ridges to the outer side of each plate, giving to the surface the appearance of several small rope ladders side by side, as in the rigging of a ship. This peculiar style of ornament is well shewn in the figures of *D. longidactylus* (Hall), Pal. N. Y., vol. 2, fig. 7*a*, plate 42, but the pattern is somewhat different; in that species the transverse ridges diverge from each other at an angle of about 45

degrees, but in this the divergence is only about 20 degrees, producing to the eye a very different effect.

Explanation of Figures. Plate III.

Figure 3*a*. Anterior side.
" 3*b*. Part of surface of proboscis, enlarged.
" 3*c*. Portion of column, enlarged.

Locality and formation.—Upper part of the Trenton limestone, near the Toll-gate, St. Lawrence Street, Montreal.

Dendrocrinus humilis, Billings.

Plate III. Figure 4.

(D. humilis, *Report Geological Survey of Canada*, 1856, p. 270.)

Description.—Cup small, conical ; arms, nearly as broad as the first primary radials, divided at the fourth or fifth joints, and again above; the basal plates are small, their height about equal to their width, the sub-radials three times larger than the basal plates ; the first primary radials are low and broad ; column, unknown ; height of cup, two and a half lines, breadth at the margin, the same.

Explanation of Figures. Plate III.

Figure 4. Posterior view of the only specimen discovered.

Locality and formation.—Trenton limestone, City of Ottawa.

Dendrocrinus latibrachiatus, Billings.

Plate III. Figures 5*a*, 5*b*, 5*c*.

(D. latibrachiatus, *Report Geological Survey of Canada*, 1856, page 270.)

Description.—This species is most closely related to *D. humilis*, the only difference being in the greater breadth and length of the arms, which at the base are quite as wide as the first primary radials, and become a little broader above, whereas in the other species they become narrower from the base upwards. The bottom of the cup is more rounded than in *D. humilis*, and as the columns of both are unknown and as they occur in different formations, they cannot be easily identified at present ; the arms are three times divided ; length of cup, three lines and a half ; of the arms, ten lines.

EXPLANATION OF FIGURES. PLATE III.

Figure 5*a*. View of the left side, shewing the left anterior ray, which has the first and second primary radials included in the cup.
" 5*b*. View of the anterior side.
" 5*c*. The posterior side.

Locality and formation.—Hudson River group, Charleton Point, Anticosti.

DENDROCRINUS SIMILIS, Billings.

(D. SIMILIS, *Report Geological Survey of Canada*, 1856, page 267.)

Description.—Cup, small, conical and sub-pentagonal; arms, long, three or four times sub-divided, rather broadly rounded on the back, and comparatively stouter than those of any of the above described species. Of the two arms preserved in the specimen examined, one remains single for a distance of two lines and a half, and then divides; there are five joints in the undivided part; the other arm shews but two joints in the part below the first bifurcation. The column for seven lines below the basal is pentagonal, with round edges and slightly concave faces; it is composed of alternately thick and thin joints, nine of each in the space of two lines, diameter of column nearly one line; length of arms sixteen lines, and the diameter at the undivided part nearly a line on the back.

Locality and formation.—Trenton limestone, City of Ottawa.

The last three species appear at first sight to be identical, but the moment a magnifying glass is brought to bear upon them, their differences become quite as apparent as those of the large species. In *D. acutidactylus* the arms are exceedingly thin and sharp on the back above the first division like the edge of a knife, and the column is circular and composed of round edged joints, which at the distance of one-half or three-fourths of an inch become nearly globular. In *D. proboscidiatus* the column at the base of the cup is pentagonal with the angles so strongly projecting, and the faces so concave that a single joint has the form of a five-rayed star; the arms, judging from the fragments seen, were very similar to those in *D. acutidactylus*.

In *D. similis* the column is only different from that of *D. proboscidiatus* by the unequal thickness of the joints, and in being more regularly pentagonal; its faces are only slightly concave, its arms also are five times thicker.

Dendrocrinus rusticus, Billings.

Plate III. Figures 7*a*, 7*b*.

(D. rusticus, *Report Geological Survey of Canada*, 1856, page 270.)

Description.—The base of the cup in this species is broad, like that of *D. conjugans;* the basal plates about as high as they are wide, the sub-radials one-third higher than the basal plates; the arm-plates a little shorter than the sub-radials, and broader than high; the azygos inter-radial is about the size of one of the basal plates, and bears three or four small plates upon its summit; the column is round at its junction with the basal plates, and composed of thin plates; but one line and a half below it becomes pentagonal, with raised rounded edges and concave faces; at the distance of two inches below the base there are about three joints of equal thickness to one line in breadth; the arms appear to have been short; breadth of cup, two lines and a half in one specimen and three lines in another; height of latter to the top of the inter-radial, four lines and a half; the whole surface is smooth. The specimens examined are imperfect, but to each there are about three inches of the column attached.

Explanation of Figures. Plate III.

Figure 7*a*. A specimen very imperfect.
" 7*b*. A small portion of the column, enlarged.

Locality and formation.—Trenton limestone, City of Ottawa.

Dendrocrinus conjugans, Billings.

Plate IV. Figures 1*a*, 1*b*, 2*a*, 2*b*.

(D. conjugans, *Report Geological Survey of Canada*, 1856, page 268.)

Description.—In this species the column about one inch below the base is round, smooth, and from half to two-thirds of a line in diameter; proceeding upwards it rapidly enlarges to two or three lines, at the base of the cup, which is small, and not much broader at the

margin where the arms become free, than it is at the bottom; the basal plates are low and broad, the sub-radials double the height of the basals and the arm-bearing plates rather more than two thirds the length of these latter; the arms half the breadth of the plates on which they stand, and broadly rounded on the back; they all divide at the height of about three lines, and again at the same distance above; there are three or four joints in each of the undivided portions. The ray on the left-hand side of the base of the proboscis, which in the generic description is said to have two of its plates included in the cup, in this species has the second plate free, with the exception that it is united on one side to the plates of the proboscis; it is however nearly as broad as the first radial plate upon which it stands, and one-third wider than the first free joint of the arm which rests upon it. This character connects *Dendrocrinus* with *Cyathocrinus*, in which the second joint of the ray in question is entirely free. The column as before mentioned is circular, broad at the base of the cup, and rapidly diminishing in size for a short distance below; it is in this part smooth, but farther down enlarges again, and is composed of thick round-edged compressed spheroidal joints very similar to those of *Heterocrinus Canadensis*. In one perfect specimen the height of the cup is three lines, the diameter of base two lines and a half, and at the margin three lines and a half; length of the arms to first division three lines and a-half, to second division six lines; width of arm to second free joint one line, and of the proboscis the same. In another individual this organ is wider than the arm; in a third specimen the arms divide at the fifth joint, but in every other respect it is the same as this species, although slightly more slender.

Explanation of Figures. Plate IV.

Figure 1*a*. Anterior side.
" 1*b*. Column, a little enlarged.
" 2*a*. Side view of a specimen.
" 2*b*. Column of same, enlarged.

Locality and formation.—Trenton limestone, City of Ottawa.

Dendrocrinus Jewettii, Billings.

Fig. 15.

Figure 15. View of the anterior side of *Dendrocrinus Jewettii.*

Description.—Cup, conical, six lines in height; arms, large, several times sub-divided, broadly rounded or sub-carinate on the back. The plates are all more or less convex, and appear to have a set of obscure radiating ridges arranged as follows: 1st. On each of the basal plates there are two ridges which run from the centre of the plate upwards, and are continued to the centres of the two sub-radials that rest upon its upper sloping sides. 2nd. On each of the sub-radials there are four ridges, two of which are the continuations of the ridges from the basal plates, while the other two run from the centre of the plate upwards, and are continued on the first primary radials to the bases of the arms. The rays consist each of one large joint, included in the cup, and four smaller ones, above which they are divided. The large joint of the left anterior ray is hexagonal; the same joint in each of the other four rays is pentagonal. The azygos sub-radial is heptagonal, and supports upon its upper side a hexagonal azygos inter-radial, which, in its turn, supports the proboscis. Column, unknown. Height of basal plates, two lines; width at base of each, one line; width measured between the two upper lateral angles, one line and a half; height of sub-radials, three lines; width of first primary radial, two lines and a half; height, two lines; the four succeeding joints of the arms are each half a line high.

This species is allied to *D. humilis* and *D. latibrachiatus*, from both of which it differs in having the plates convex and ridged.

It was discovered by Col. E. Jewett, of Utica, N. Y., and by him kindly communicated to us for description. Through the researches of this gentleman our knowledge of the Silurian fauna of North America has been greatly extended. Many of the most rare and interesting fossils figured in Hall's Palæontology of New York are his discoveries; and it gives me much pleasure to dedicate this new crinoid to him.

Locality and formation.—Bay of Quinte, Trenton limestone.

Dendrocrinus cylindricus, Billings.

Plate III. Figures, 8*a*, 8*b*.

Description.—Cup, small, two lines and a half in height, and about the same in width at the margin; arms, cylindrical, one line in width at the base, divided above the third free joint; length of the undivided portion, two and a half lines, each one of the three free joints being nearly one line in length. The proboscis is large, equal to the arms in height, and composed on the anterior side of large plates, the first, second, third and fourth of which are each rather more than one line in length. All the plates are smooth. The column is round, smooth, and composed of very thin joints, which however vary a little in thickness, ten in the length of one line. Length of body and arms, one inch and one-fourth.

The above description of the column of this species refers to the upper portion only. It seems probable that in the lower part it is composed of thick, rounded joints, as I find a fragment of a column of this latter character on the same piece of stone in which the crinoid is imbedded.

Explanation of Figures. Plate III.

Figure 8*a*. Anterior side of *D. cylindricus.* That which appears to be a large arm near the left side is the proboscis.

" 8*b*. Part of the column, a little enlarged.

Locality and formation.—Near the Toll-gate, St. Lawrence Street, Montreal; Trenton limestone.

PALÆOCRINUS ANGULATUS, Billings.

Plate III. Figures 6*a*, 6*b*.

(DENDROCRINUS ANGULATUS, *Report Geological Survey of Canada*, 1856, page 269.)

Description.—In this beautiful little crinoid the plates are ornamented with radiating ridges similar to those of *Glyptocrinus decadactylus*. The cup is small, conical and pentagonal. From the centre of each of the rather large sub-radial plates there proceed six strongly-elevated ridges, one to the base of each of the two arms above the plate, one to each of the two basal plates below it, and one to each of the adjoining sub-radials. The arms are very slender, sharp on the back, and at least twice divided; the three joints of the column which remain attached to the specimen are pentagonal. Length of cup, three lines; breadth at the margin, four lines. Diameter of column, nearly one line.

EXPLANATION OF FIGURES. PLATE III.

Figure 6*a*. Left side of the only specimen discovered.
" 6*b*. Column, enlarged.

Locality and formation.—Trenton limestone, City of Ottawa.

PALÆOCRINUS RHOMBIFERUS, Billings.

Description.—This species is of nearly the same shape as *P. angulatus*, but differs in the arrangement of the surface-markings. In *P. angulatus* the radiating ridges are so disposed as to encircle the body with two horizontal rows of triangular spaces. In this species however, in consequence of the absence of the transverse ridges near the centre of the body, the spaces are rhomboids instead of triangles. The ridges are also so broad in the base that the separate plates appear to be simply bevelled from the centre to the edges. The detached plates figured on plate 4, vol. i. Palæontology of New York, under the name of *Actinocrinus*, resemble the sub-radials of this species, but are larger. Only one specimen has been collected, consisting of a perfect cup imbedded in a piece of limestone. The arms are sharp-edged on the back, and twice divided. Length of cup, three lines; and of the arms, nine lines.

Locality and formation.—Trenton limestone, City of Ottawa.

PALÆOCRINUS PULCHELLUS, Billings.

Description.—The same as *P. angulatus*, but with a round column. The surface of the specimen is a good deal eroded, and yet it can be seen that the surface is radiated, as in *P. angulatus.* The column is well preserved, and is one line wide at the base of the cup, from which point it rapidly tapers to the thickness of half a line at the length of four lines. Length of cup, three lines.

Locality and formation.—One specimen from the Trenton limestone, City of Ottawa.

Genus LECANOCRINUS, Billings.

(LECANOCRINUS, Hall, *Palæontology of New York*, volume ii., page 199.)

FORMULA :

Basal plates, 3.	Radials, 1×5.
Sub-radial plates, 5.	Azygos inter-radials, 1–3.

Generic characters.—In this genus there are three basal plates, one of them pentagonal and the other two hexagonal; in the second series there are five sub-radial plates, two of which are supported by the two hexagonal basal plates, while the other three alternate with these latter. Alternating above the sub-radials are five primary rays of three joints each, and above these, ten secondary rays. Some of the species have several small inter-radial plates in one or more of the divisions between the primary rays.

I have placed the following species in the above genus, although it appears probable that some other disposition should be made of them. The specimens are not sufficiently perfect to enable me to make out all the characters; and as they are more nearly related to *Lecanocrinus* than any other Silurian genus, it seems to be the better course to arrange them in that group provisionally.

Lecanocrinus elegans, Billings.

Plate IV. Figures 4*a*, 4*b*.

(L. elegans, *Report Geological Survey of Canada*, 1856, page 278.)

Description.—Cup, small, conical, three lines in height from the base to the upper margin of the first primary radial plate, at which level the breadth is also about three lines; the breadth of the base is one line and a half, and the top of the column scarcely less; the first primary radials are a little broader than high, and rendered slightly heptagonal by the truncation of their upper lateral angles; the second primary radials are narrower and quadrangular, or obscurely hexagonal; the third are pentagonal; the length of each is about a line and a half. The third in each of the three rays exposed in the only specimen seen, supports two secondary rays of five joints each, and then divides into two tertiary rays; these latter are again divided. The rays above the fourth division are articulated in two series. Between the primary rays are several small interradials. The column is circular, with round-edged joints, from four to six in one line; length of ray from the base of first primary radial to the extremities, one inch and one fourth.

Explanation of Figures. Plate IV.

Figure 4*a*. A specimen shewing one of the hexagonal basal plates.
" 4*b*. Several joints of the column, a little enlarged.

Locality and formation.—Trenton limestone; City of Ottawa.

Lecanocrinus lævis.

Plate IV. Figure 3*a*.

(L. lævis, *Report Geological Survey of Canada*, 1856, page 278.)

Description.—This species is shorter than the preceding, and has only four joints instead of five in the secondary rays; the upper part of the column is round and smooth. In other respects there is much resemblance between the two, but still I think them distinct.

Explanation of Figures. Plate IV.

Figure 3*a*. A specimen slightly crushed.

Locality and formation.—Trenton limestone; City of Ottawa.

Genus Heterocrinus, Hall.

(Heterocrinus, Hall, *Palæontology of New York*, volume i., page 278.)

Fig. 16.

Figure 16. Diagram of the structure of the genus *Heterocrinus*.

Generic characters.—The species of this genus are small, and, including the arms, long and nearly cylindrical crinoids. The base is composed of five plates, above which are five long rays, without any intervening sub-radial plates. The number of radial plates in each ray is variable. The cup appears to consist of the primary radials, while the free rays or arms commence with the first plates of the secondary rays. There are one or two small azygos inter-radials, but no regular inter-radials. The arms are pinnulated.

Heterocrinus Canadensis, Billings.

Plate IV. Figs. *5a–5d.*

(Compare *H. simplex*, Hall, *Palæontology of New York*, volume i., page 280.)

Description.—Sub-cylindrical or elongated, fusiform; length, including the rays, from one to two inches; diameter at half the length, from three to four lines. The base in the large specimens is about one line and a half in diameter, and the body gradually enlarges to about three lines at that point where the rays divide. The diameter above is always greater, the extent depending upon the amount of expansion of the rays in the particular specimen examined. The basal plates are scarcely a line in height; the length of the undivided portions of the rays in the large individuals is about three lines.

The right anterior ray consists of three joints, the first equal in length to the other two, and with one of its angles truncated where it is in contact with the azygos inter-radial. The left anterior ray has four joints, the second being the longest, and having one of its angles truncated to support the inter-radial. The other three appear to consist each of four equal joints. The upper joint of each ray is pentagonal, and supports two secondary rays, which continue single to their extremities. The azygos inter-radial is oblong, higher than wide, five-sided, two of the sides meeting to form an obtusely-pointed lower extremity, which rests wedge-like between the truncated angles of the first joint of the ray upon the left, and the second joint of the ray on the right; its upper side is horizontal and supports another plate, which is probably the base of a proboscis. The secondary rays, ten in number, consist each of a series of oblong, quadrangular joints, usually one line in length and two-thirds of a line in breadth.

There is a row of long pinnulæ upon each of the inner margins of each ray; they rise upwards, nearly parallel with the rays, instead of projecting at nearly right angles, as in other species. The column is round and smooth at the base of the pelvis, below which it tapers and becomes very slender at the distance of one or two inches, then slightly larger and composed of compressed globular joints, the rounded edges of which, to the eye, present a bead-like appearance. The longest column seen with the head attached was fifteen inches; and, as it was broken off below, it had been probably several inches longer. The diameter is usually somewhat less than a line, and there are about seven joints of equal size to two lines in length. The smooth, slender, upper portion of the column, near the base of the cup, is generally half a line or a little more in diameter, expanding to twice or three times this size at the base.

H. simplex, according to Professor Hall, has the column at the base of the cup pentagonal, but is otherwise closely allied to *H. Canadensis*. (See description of *H. simplex* in the Palæontology of New York, volume i., page 280.)

Explanation of Figures. Plate IV.

Figure 5*a*. A specimen with part of the column attached.
" 5*b*. Portion of the column, enlarged.
" 5*c*. Anterior side of a different specimen.
" 5*d*. A specimen which has the pinnulæ preserved.

Locality and formation.—Trenton limestone, Ottawa and Montreal.

Heterocrinus tenuis, Billings.

Plate IV. Figures 6*a*–6*b*.

(H. tenuis, *Report Geological Survey of Canada*, 1856, page 273.)

Description.—Much smaller than *H. simplex;* arms, long, very slender, and several times divided; column, very obscurely pentagonal, composed of sub-globular joints; proboscis, extending nearly to the apices of the arms; length, including the arms, from ten to sixteen lines; without the arms, from one and a half to two and a half lines; diameter at base of arms, about two lines; of column, at base of cup, half a line.

It is not certain that this species should be referred to the genus *Heterocrinus.* The plates of all the specimens in the collection are so closely united that their number and arrangement cannot be satisfactorily made out. The weight of the evidence is in favor of the genus under which I have placed it. The species, when several times attentively examined, is easily distinguished from *H. simplex.* In that species the column, for a short distance below the cup, is smooth and slender, and it enlarges suddenly from a few lines below, until it forms rather a broad base for the pelvis to stand upon. But in *H. tenuis* the column continues moniliform to the base of the cup and without enlarging, but on the contrary is rather less in diameter at the point of contact than it is below. In one specimen there are forty two joints in the first nine lines from the pelvis, and some irregularities in the size can be seen. They are thinner near the cup and gradually become thicker, so that at two inches from the pelvis there are only sixteen in half an inch. The arms, although much more slender than those of *H. simplex*, usually lie folded together, or but slightly separated.

Explanation of Figures. Plate IV.

Figure 6*a*. A specimen with part of the column.
" 6*b*. A few joints of the column, enlarged.

Locality and formation.—Trenton limestone, Ottawa and Montreal.

HETEROCRINUS INÆQUALIS, Billings.

Plate IV. Figure 7*a*.

Description.—Cup, pointed at the base; rays, large, rounded on the back, and inequally divided. In the specimen figured, the two first primary radial plates which can be seen are long and nearly triangular, their lower acute angles meeting in the base of the cup and their upper straight sides supporting free rays or arms. Only three of the rays are visible in the specimen, the others being imbedded in the matrix. One of these (partly shewn at the left side of the figure,) appears to be simple or undivided throughout. It is nearly cylindrical, and consists of a series of large, transversely oblong joints, one line and one fourth in width and two thirds of a line in height. Its lower extremity is concealed, and I have not been able therefore to ascertain whether or not it originates in the base of the cup. The central ray (of the figure) divides above the third joint into two equal secondary rays, which are also several times subdivided. In these subdivisions of the secondary rays, however, the branches are of an unequal size, one of them in each instance being about one-fourth the thickness of the other. The other ray (partly exposed in the specimen,) is undivided from the base to the fifth joint inclusive, above which it is buried in the stone. The surface is minutely granular.

I have placed this remarkable species in *Heterocrinus* provisionally, as it most resembles species of that genus. When its structure shall have been ascertained, it may be necessary to refer it to some other genus.

Locality and formation.—Trenton limestone, Ottawa.

HETEROCRINUS ARTICULOSUS, Billings.

Plate IV. Figure 8.

Description.—Of this species we have only a single ray, which much resembles one of the rays of *H. inæqualis*, but is nevertheless decidedly distinct. The secondary rays are irregularly jointed, the plates where the branches are given off being broader than elsewhere. In consequence of this character the rays have a peculiarly knotty appearance. It is probable that this species and *H. inæqualis* will, when all their characters are known, constitute a new genus.

Locality and formation.—Trenton limestone, Ottawa.

Genus Cleiocrinus, Billings.

(Cleiocrinus, *Report Geological Survey of Canada*, 1856, page 276.)

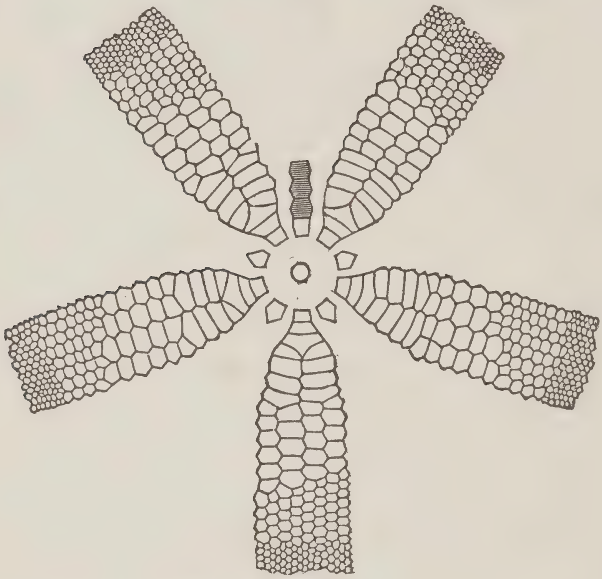

Fig. 17.

Figure 17. Diagram of the structure of the cup in the genus *Cleiocrinus.*

Generic characters.—Cup, large, conical or pyriform; basal plates, five; rays, five, alternating with the basal plates; the third plate of each ray is pentagonal and bears two secondary rays, which are several times divided above. Between two of the rays a single vertical series of azygos inter-radial plates extends from the base to the margin of the cup. The azygos plates and rays are all firmly anchylosed together by their lateral margins up to the height of the fifth or sixth sub-division. The column is pentagonal or nearly round.

This genus has the structure of a *Pentacrinus*, with numerously divided arms all soldered together in the walls of the cup.

CLEIOCRINUS REGIUS.

Plate V. Figures 1*a*–1*g*.

(CLEIOCRINUS REGIUS, *Report Geological Survey of Canada*, 1856, page 277.)

Description.—Cup, elongate, conical, gradually expanding from the base until near the top, where it is slightly contracted. The margin supports about forty long, very slender, tentaculated, free rays. At first sight there appear to be ten small basal plates, but upon examination five of these are found to be the first plates of the five rays which rest immediately upon the upper joint of the column; the other five are the true basal plates. Four of these latter are pentagonal, and the fifth, which supports the series of inter-radials, is nearly square; height of each basal plate, one line; breadth, the same; the small radial plates which rest on the column between the basal plates are a little broader than these latter, but not so high; the column is pentagonal, and the basal plates are placed upon the angles of the upper joint, while the bases of the rays are situated upon the straight edges: there are about two joints of the column to one line, and they are alternately thicker and thinner; the column near the lower extremity becomes round and suddenly expands into a broad base of attachment.

The surface of the cup is nearly smooth, slightly marked by obscure, vertical, rounded ridges along the centres of the rays and of their sub-divisions.

Length of cup, one inch and three-fourths; breadth near the margin, about one inch; diameter of column, from two to four lines. Nearly all the large pentagonal columns in the Trenton limestone at the City of Ottawa belong to this species.

EXPLANATION OF FIGURES. PLATE V.

Figure 1*a*. A nearly perfect cup of this species.
" 1*b*. The base, shewing the small basal plates, with the quadrangular first primary radials between them.
" 1*c*, 1*d*, 1*e*, and 1*f*. Fragments of the column.
" 1*g*. The base of the column.

Locality and formation.—Trenton limestone, City of Ottawa.

Cleiocrinus grandis, Billings.

Plate V. Figures 2*a*–2*c*.

Description.—The column of this species is large, obscurely pentagonal, and composed of thin joints, every alternate one of which is about one fourth of a line wider than the one on each side of it. In consequence of this inequality in the size of the joints the column is closely annulated with slightly projecting rings, from six to eight in three lines. When perfect it is rounded-pentagonal, but when crushed it divides into five longitudinal lobes, as represented in figure 2*b*. Each joint appears to be composed of five pieces, and the articulating surfaces are striated with numerous fine, curved, radiating ridges. The radix or base of attachment of the column consists of a number of large roots, which appear to be composed of small polygonal plates. The alimentary canal is very large and nearly circular.

These columns have so nearly the structure of those of *C. regius*, that I have no doubt they belong to a species of that genus.

Explanation of Figures. Plate V.

Figure 2*a*. Portions of two individuals of this species, which appear to have grown upon the same spot.
" 2*b*. Fragment of a column, crushed.
" 2*c*. Transverse section, shewing the large alimentary canal.

Locality and formation.—Trenton limestone, Ottawa.

Cleiocrinus magnificus, Billings.

Plate V. Figure 3.

Description.—In this species the column is nearly round and composed of thin joints, of which there are from six to eight in two lines. The alimentary canal is pentagonal, and six lines in diameter where the column is nine lines. The cup has never been seen, but the size and form of the fragments of the stalk are sufficient to distinguish this species from any other in the Trenton limestone. It appears to belong to the genus *Cleiocrinus*. Diameter of column, from nine lines to one inch.

Locality and formation.—Trenton limestone, City of Ottawa.

Genus Glyptocrinus, Hall.

(Glyptocrinus, Hall, *Palæontology of New York*, volume i., page 280.)

Formula :

Basal plates, 5.	Regular inter-radials, 6.
Radial plates, 3×5.	Azygos inter-radials, 7 or more.

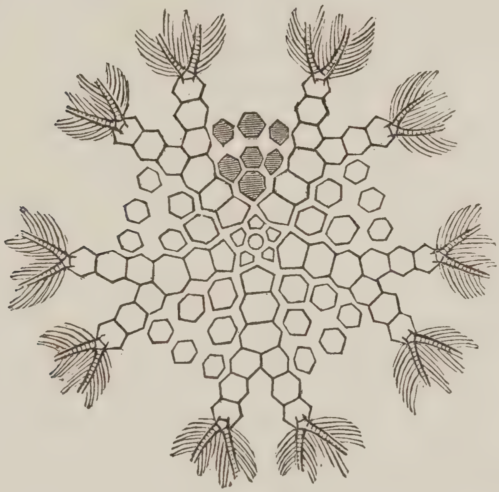

Fig. 18.

Figure 18. Diagram of the structure of the cup in the genus *Glyptocrinus.*

Generic characters.—Cup, pyriform, globular or oval, in some species very large; arms, long, densely fringed with pinnulæ; base, composed of five plates, which are either pentagonal or hexagonal; regular inter-radials, usually six; azygos inter-radials, seven or more; column, round or sub-pentagonal, strongly annulated or moniliform in all the species known.

The plates of the species of this genus are flat, thin, and either smooth or ornamented with radiating ridges, striæ or raised margins; the large joints of the columns are often nodulose. In the Black River and Trenton limestones in Canada, the remains of several species are exceedingly abundant, but usually reduced to mere fragments of the plates and column. At the city of Ottawa, where these

rocks are exposed on a large scale, three of the species hereinafter described, *G. priscus*, *G. ramulosus*, and *G. marginatus*, appear to be more common than at any other locality yet examined. The heads are frequently found there in a fragmentary state, but good specimens are rare. *G. priscus* is the only head collected in the Black River limestone, but it also occurs in the Trenton. I have met with *G. lacunosus* near the top of the Trenton limestone only. *G. ornatus* is found about the middle of the deposit, rather common, and in fewer numbers upwards to the Utica slate. There is a sixth species which also occurs at Ottawa, but is only known by its very characteristic sub-pentagonal column.

Glyptocrinus priscus, Billings.

Plate VII. Figures 1*a*–1*f*.

(G. priscus, *Report Geological Survey of Canada*, 1856, page 287.)

Description.—The cup of this species is pretty regularly oval, covered with smooth plates and surmounted by ten long undivided fingers or free rays, which are densely fringed with two rows of pinnulæ. A strong rounded carina, or ridge, runs up each of the primary rays, and, dividing into two upon the centre of the third plate, sends a branch up each of the secondary rays to the base of the fingers; the carinæ are also divided upon each of the basal plates, and coalesce into one on the centres of the first primary radial plates; in the azygos inter-radius a sixth ridge ascends to the top of the cup, dividing the space into two parts about equal; it bifurcates below on the centre of the large azygos, one branch proceeding to the centre of each of the two contiguous first primary radial plates. The basal plates are of a moderate size, but the first radials are large, broad, and in contact with each other by their upright lateral margins. The joints of the free rays are thin and very closely set. The rays are also rather broadly rounded on the back. As to the column, the only perfect head in the collection has but a single joint attached to its base, but the columns found associated with it and also those which have been observed in the Trenton limestone at Ottawa, along with the fragments of the heads of individuals of this species, are round, with the large joints rather thick and rather nodulose. I think this species grew to a very large size; but the evidence is not sufficient to connect positively the small specimen

examined with the large ten-fingered fragments found in the Trenton limestone.

Explanation of Figures. Plate VII.

Figure 1*a*. View of the posterior side of *G. priscus*.
" 1*b*. Anterior side of the same specimen.
" 1*c*., 1*d*., 1*e*., 1*f*. Columns found associated with 1*a*.

Locality and formation.—One small perfect head collected at the upper mouth of the cave at the fourth chute of the Bonnechère, in the County of Renfrew, in the Black River limestone. Fragments of the heads and columns apparently referable to this species are common in the Trenton limestone at Ottawa.

Glyptocrinus ramulosus, Billings.

(G. Ramulosus, *Report Geological Survey of Canada*, 1856, page 258.)

Description.—The cup of this species very much resembles that of *G. priscus*. It is covered with smooth plates, and the primary and secondary rays are strongly keeled, but the base is broader, the basal plates smaller in proportion to the size of the body, and there are twenty free arms springing from the margin instead of ten, as in *G. priscus*. The arms also are several times bifurcated at various distances from the top of the cup, while those of the former species remain single to their extremities; the pinnulæ are in two rows, and from one-fourth to three-fourths of an inch in length; the ossicula of the arms are very thin, and interlock with each other so deeply that each seems to extend completely across, giving the appearance of but a single series of joints where in fact there are two. Near the base of the arms there are two joints in about one line, but higher up there are from four to eight in the same length. The arms are regularly rounded on the back, and comparatively slender, being scarcely more than one line in diameter at the base of the largest specimens. In the specimens examined four of the plates of each of the secondary rays are included in the general test of the body. The column is round, and at the base of the cup the large projecting joints are thin, sharp-edged, and crowded close together; they gradually become farther apart as the distance from the base of the cup increases, until at length they are from one to three lines removed from each other. Between these large joints the column is composed of very thin plates with crenulated margins, the projecting teeth of

one plate fitting into the corresponding notches of those in contact with it above and below. The edges of the large joints are nodulose, and the column is much larger at the base of the cup than at its lower extremity. One specimen tapers from one-fourth of an inch to one-eighth in a length of fifteen inches.

The form of the alimentary canal appears to vary in different parts of the same column, being usually more or less star-shaped, but sometimes circular. The separate large joints are generally seen in the shape of flattened rings, with the outside margin thick and rounded, but thinned down to a sharp edge around the perforation of the centre.

The columns of this species very much resemble those of *Schizocrinus nodosus* (Hall, Palæontology of New York, vol. i., pl. 10), and were always so called in Canada, until a number of specimens were found with the heads attached. The figures and description of that species however given by Professor Hall, show that it had four plates in the primary rays, and must be therefore not only specifically but generically distinct from *G. ramulosus*. I think that a large proportion of those great columns so common in the Trenton limestone on the Ottawa should be referred to this species and to *G. priscus*. Specimens four or five feet in length are sometimes seen in the quarries, and some of the crushed heads, including the arms, are seven inches in length.

A highly interesting specimen in the cabinet of Dr. Van Cortlandt of the city of Ottawa, consists of the inside of a cup two inches and a half in length and one inch and seven-eighths in diameter, at the base of the free arms. It had been completely embedded in the stone, but by some means the body has been extracted, leaving all the plates lining the cavity in their natural position. Each of the plates has a small tubercle in its centre, on the inside. The impression of a fragment of the column one inch and a half in length from the base of the cup downwards still remains. The characters of the column are precisely those of many of the large ones usually seen without the heads attached. If therefore any of these large columns belong to this species, then in their advanced age they must have lost their nodulose character, because they are smooth instead of nodose, as is the case with the smaller specimens in the collection of the Survey which have the heads attached. It appears to me that in all the species of *Glyptocrinus* the columns were ornamented until past the middle age, and that afterwards they became plain.

EXPLANATION OF FIGURES. PLATES VII. AND VIII.

Plate 7, figure 2*a*. A cup of medium size.
" 2*b*. Portion of the column near the base of the cup.
" 2*c*–2*f*. These figures represent different parts of a very long column.
Plate 8, figure 1*a*. A crushed specimen, with part of the column attached.
" 1*b*. The column of 1*a*, enlarged.
" 1*c*, 1*d*. Columns found along with 1*a*.

Locality and formation.—Trenton limestone, City of Ottawa, Island of St. Joseph, in Lake Huron.

GLYPTOCRINUS MARGINATUS, Billings.

Plate IX. Figure 1*a*.

(G. MARGINATUS, *Report Geological Survey of Canada*, 1856, page 260.)

Description.—The plates of this fine species are all margined by a strong elevated border, the effect of which is to give to the surface a beautifully reticulated appearance. The only specimen in the collection is crushed, but then the size of the plates near the bottom shows that it had a broad, rounded base, and that its general form was sub-globular. The azygos inter-radial space contains ten plates below the level of the base of the secondary rays; the rays are all carinated, and there is also an upright row of small plates (in the centre of the azygos inter-radial space) which exhibits a faint keel. There are four or five of the secondary radial plates included in the cup. A piece of the column two inches and a half in length remains attached, and shows that the large joints at the base of the cup of this species were much thicker, and consequently not so sharp-edged as those occupying a similar position in the other species.

The length of this cup from the base to the free arms is one inch and a half, and the breadth about the same. The column is four lines in diameter, and in the length of two inches and a half there are twenty-one large joints with the same number of others a little smaller, each situated half way between two of the largest. The arms are not preserved in the specimen.

This species also grew to a large size, and was closely related to both *G. priscus* and *G. ramulosus*.

EXPLANATION OF FIGURES. PLATE IX.

Figure 1*a*. View of the only specimen collected.

Locality and formation.—Trenton limestone, City of Ottawa.

Glyptocrinus ornatus, Billings.

Plate IX. Figure 2*a*.

(G. ornatus, *Report Geological Survey of Canada*, 1856, page 260.)

Description.—In the specimens of this species that have been collected the cup is broad-oval, the base well rounded, but narrower than the upper extremity; the rays (as in the other species) are keeled, and there are ten long, slender, undivided free arms, as in *G. priscus.* Each of the plates is ornamented with five or six sharp ridges, which radiate from the centre, thus covering the body with numerous stars with triangular interspaces. The column is round, and the large joints are thin, sharp-edged, and distant from each other half a line at and near the base of the cup in a specimen of the ordinary size.

Length of the cup in several specimens, a little more than half an inch; diameter at the base of the free rays, about the same; diameter of column at the base of the cup, about one line.

The surface ornament of this species is very like that of *G. decadactylus* (Hall) of the Hudson River group; but there is a very decided difference in the form of the columns of the two. Those figured by Professor Hall have the large joints very thick and rounded, while in *G. ornatus* they are exceedingly thin and sharp-edged; some of our specimens are very like the figure of *G. basalis* (McCoy), given on page 180 of Sir Roderick Murchison's Siluria, 1st edition. In Sedgwick and McCoy's British Palæozoic Rocks, (p. 57) however, that species is described by Prof. McCoy as having the pelvic plate immediately below the large inter-radial space, hexagonal, and supporting upon its upper truncated margin the large inter-radial. In our species all the pelvic plates are very small and pentagonal. To both the English and New York species ours is evidently closely allied.

Explanation of Figures. Plate IX.

Figure 2*a*. Anterior side of a specimen of *G. ornatus*.

Locality and formation.—Upper half of the Trenton limestone, City of Ottawa.

Glyptocrinus lacunosus.

Plate VIII. Figures 3*a*–3*e*.

(G. lacunosus, *Report Geological Survey of Canada*, 1856, page 261.)

Description.—This species is characterized by its very large basal plates, one of which, that beneath the azygos inter-radial space, is hexagonal, and supports upon its upper truncated edge the first azygos inter-radial. The surface of the body is completely covered with small rugose pits and wrinkles; the rays become free at the second or third secondary radial plate; they divide immediately after becoming free, at least once, perhaps again above, but the specimens do not shew them perfectly above the first sub-division. The body is sub-globular, about three-quarters of an inch in length, and the same in breadth.

The column is round, and when once carefully examined is easily distinguished from that of any other species occurring in the Trenton limestones. The large joints are proportionally very broad and projecting, while the constrictions between them are wide and deep. At the distance of from six to ten inches from the base of the cup the large joints disappear altogether, and the column becomes smooth, like that of the genus *Rhodocrinus.* In one specimen, at the distance of three inches from the base of the cup, the large joints are nearly one line in thickness at their edges, and are two lines distant from each other; they are also two and a half lines in diameter; the constricted portion of the column between them is scarcely one line.

Explanation of Figures. Plate VIII.

Figure 3*a*. A specimen with part of the column attached.
" 3*b*. Fragment of a different specimen.
" 3*c*, 3*d*, 3*e*. Columns of this species.

Locality and formation.—Upper half of the Trenton limestone, City of Ottawa.

Rhodocrinus pyriformis, Billings.

Plate VI. Figures 1*a*–1*d*.

(Thysanocrinus [Rhodocrinus] pyriformis, *Report Geol. Survey of Canada*, 1856, p. 263.)

Description.—Cup, conical or pyriform, the adult specimens about two inches in length and one inch and a half in their greatest

diameter, which is near the base of the free rays. The basal plates are pentagonal, with an obscurely-rounded ridge across their base; sub-radials, hexagonal, each supporting upon its truncated upper margin a large inter-radial. The first primary radial on each side of the azygos inter-radial space is hexagonal, the other three are pentagonal; the second plates in the rays are hexagonal, and the third heptagonal; each of the latter supporting upon its upper sloping edges the bases of two secondary rays, which become free at the third or fourth plate, thus furnishing ten arms, which divide at not quite one-fourth of an inch from their base, and again at half an inch; the full grown arms are again subdivided, some of them once, others twice. The arms are comparatively short, not exceeding two inches in length in a specimen whose cup measures one inch and a half in length. The ossicula which constitute the double series of joints of the free rays or arms, are obtusely cuneiform, the two rows interlocking with each other so slightly that the points of the joints extend but a short distance across the centre of the back of the arm; there are two ossicula to one line in length in that portion of the arm at the base which is situated next the cup, and below the first sub-division; the arm here is scarcely one line in thickness. All the plates are smooth or slightly granulated on their surface; in some of the specimens there is a trace of an obscurely-elevated margin round the plates, and there is also a broadly-rounded keel, not very prominent, upon each of the primary and secondary rays.

The column is round, slender, annulated, with thin but round-edged projecting joints, for several inches below the bottom of the cup; it then becomes smooth, and continues of an uniform size to the base of attachment, which consists of a number of root-like branches. The annulated portion of the column is usually found a little curved, but the smooth, cylindrical portion is always straight, and in this part there are about ten joints to two lines of the length; near the cup there are three or four annulations to two lines. The diameter of the column is from one and a half to two lines and a half, and the length varies greatly; one specimen, a very perfect impression of the head, column and root, all in their natural connection, measured but seventeen inches in length; a fragment of the smooth portion of a column still lying in the rock measures thirty-seven inches and a half. At Ottawa, in the upper part of the Trenton limestone, there are fragments of smooth, round columns, four or five lines in diameter, which appear to be a large variety of this species.

EXPLANATION OF FIGURES. PLATE VI.

Figure 1*a*. A specimen with part of the column attached.
" 1*b*, 1*c*. Crushed specimens.
" 1*d*. The radix of this species.

Locality and formation.—Trenton limestone, City of Ottawa, plentiful; also in the upper part of the same formation, around the base of the mountain at Montreal, where the columns are rather common.

RHODOCRINUS MICROBASALIS, Billings.

Plate VI. Figure 2.

(THYSANOCRINUS [RHODOCRINUS] MICROBASALIS, *Rep. Geol. Survey of Canada*, 1856, p. 264.)

Description.—The specimens for which the above specific name is proposed are about five-eighths of an inch in height, and the same or a little more in breadth at the top. They are cup-shaped, and uniformly expanding from the narrow base upwards. The basal plates are so small that they can only be well seen when the column is removed. The rays are keeled, and all the plates of the body exhibit obscure, radiating ridges, somewhat similar to those of *Glyptocrinus ornatus*, but not so prominent. The column is round, annulated in its upper and smooth in its lower part. I have not seen either the root or the arms.

This species is closely allied to *R. pyriformis*, but differs in its much smaller size, in the comparative minuteness of the pelvic plates, and also in the character of the surface. *R. pyriformis* is a large, smooth species, but this one has a surface ornamented with stars, only well seen however on good specimens.

Locality and formation.—Trenton limestone, City of Ottawa.

Genus RETEOCRINUS, Billings.

Generic characters.—This remarkable genus has no perfectly formed plates. The cup consists of a reticulated skeleton, composed of rudimentary plates, each consisting of a central nucleus, from which radiate from three to five stout processes. Of such plates there are five in the basal series, five in the sub-radial, and five in the radial series. On the azygos side the sub-radial has five processes; the others have four each.

The principal difference between this genus and such genera as *Dendrocrinus*, *Porocrinus*, *Palæocrinus*, and *Cyathocrinus*, consists in the incompleteness or rudimentary character of its plates. The arrangement of the parts of the skeleton is the same.

Reteocrinus stellaris, Billings.

Plate IX. Figures 4*a*–4*e*.

Description.—The cup of this species appears to be about five lines in height and six lines in width. The projecting processes of the plates, and also the joints of the arms to first bifurcation, are rounded on the outside, and half a line in thickness. The first joint of the right anterior ray (which is the first primary radial,) has three processes, the upper one of which supports an arm, while the two lower rest, one of them on one of the upper processes of the azygos sub-radial and the other upon a process of the right anterior sub-radial. It is probable that the other rays are constructed and situated in nearly the same manner. The azygos sub-radial has five processes, three above and two below. The central of the three upper processes supports an upright series of joints (as represented in figure 4*a*, plate 9). If this series of joints constitute a true arm, then there must be six arms in this species. The right arm divides above the fourth joint; I have not seen the other arms distinctly. The spaces between the arms are occupied by numerous small stellate plates, which may have belonged either to an integument connecting the arms, or to the covering of the abdomen. The column is round, and composed of very thin plates near the base of the cup. At the distance of about one inch and a half below the base of the cup the joints alternate in thickness.

None of the specimens collected are perfect, and the characters of the species therefore have not been fully ascertained.

Explanation of Figures. Plate IX.

Figure 4*a*. View of the anterior side of a specimen.
" 4*b*. A specimen retaining a piece of the column; 4*c*, several of the joints enlarged. They appear to be nearly equal in size, and sharp-edged at the base of the cup.
" 4*d*, 4*e*. Fragments of this species.
[In 4*a* and 4*e* the small stellate plates between the arms are represented.]

Locality and formation.—Trenton limestone, City of Ottawa.

RETEOCRINUS? FIMBRIATUS, Billings.

Plate IX. Figures 3*a*–3*c*.

Description.—Length of the only specimen discovered, including the arms, about fifteen lines; basal plates, minute; sub-radials, one line in height; arms, several times divided and furnished with pinnulæ. At the apex of each of the basal plates there is an aperture half a line in width, and another of the same size at the lower angle of each first primary radial. The primary rays, so far as they have been observed, consist each of three plates, the first heptagonal, the second hexagonal, and the third pentagonal,—the spaces between them filled with very small plates. A single joint of the column remains attached to the base of the cup. It is pentagonal, with slightly concave faces and rather sharp angles.

The specimen is very imperfect, and it is with much doubt that I refer it to the genus *Reteocrinus*.

EXPLANATION OF FIGURES. PLATE IX.

Figure 3*a*. The only specimen discovered.
" 3*b*. The base, enlarged; the unshaded pentagonal space shews the form of the upper joint of the column.
" 3*c*. One of the arms, with some of the pinnulæ attached, enlarged.

Locality and formation.—Hudson River group, Charleton Point, Anticosti.

SYRINGOCRINUS PARADOXICUS, Billings.

Plate X. Figure 14.

Description.—Of this crinoid no perfect specimens have been collected. The fragment figured exhibits in the side exposed two series of polygonal plates, so arranged that they appear to constitute part of a tube, one half of which (probably composed of two other series of plates,) is buried in the stone. At one extremity (the lower end in the figure,) this tube is one line and and a half in diameter; but as it appears to be flattened by pressure, its thickness did not probably much exceed one line when not distorted. At the other end it seems to be somewhat larger, but this may be owing to the separation of the plates. At this extremity also there appears to be

attached to the main body of the tube an additional part, composed of numerous small, elongated, irregular plates, placed transversely.

That this curious fossil is part of a crinoid, I have not the least doubt; and further, it seems quite certain that it does not belong to any known genus. The above generic and specific names are proposed for it provisionally.

Locality and formation.—Trenton limestone, Beauport, near Quebec.

Genus Comatula.

Memoir on the Star-Fish of the genus Comatula, demonstrative of the Pentacrinus europæus being the young of our indigenous species. By John V. Thompson, F.L.S., Deputy Inspector-General of Hospitals. Communicated by Sir James M'Grigor, F.R.S. *

[Extracted from *Jameson's Edinburgh New Philosophical Journal*, vol. xx., p. 295.]

"If we were told by any traveller that he had visited an unknown region, where the animals dropt their eggs on trees and shrubs, which there fixed themselves and shot up like parasitic plants on a long stem, gradually evolving, at their extreme end, member after member and function after function, until the young animals became so perfect as to resemble their parents in every essential point,—when their attachment to the connecting foot-stalk was dissolved, and they became free and locomotive, and betook themselves to the wandering life of the parent stock! few could be got to believe facts so incredible, and so much at variance with the course of nature, as made manifest everywhere and from all time; but if established on incontestable evidence, the highest degree of surprise and admiration would necessarily supplant our incredulity,—voyages would be undertaken, and the curious of every country would flock to witness such an extraordinary anomaly, at the greatest risk and expense. If, then, a fact so contrary to our experience relating to the superior classes of animals should be capable of exciting so great a degree of interest, it may be presumed that an analogous circumstance, now for the first time actually discovered in an animal belonging to one of the inferior classes, must be considered at least as highly worthy of the attention of the philosophic naturalist.

"It is no uncommon thing, in the inferior classes of the animal kingdom, to find animals permanently attached from the period of their birth, and during the whole time of their existence, familiar examples of which we have in the oyster, anomia, and various other

* Read before the Royal Society of London, in June, 1835.

bivalve shell-fish, and in numerous compound animals of the classes Zoophyta and Infusoria. I have also shewn, in my memoirs on the Cirripedes, examples of animals being free and locomotive in their first stages, and afterwards becoming permanently fixed; but an animal growing for a period as it were a flower, fixed by its stem, and then dropping from its pedicle and becoming, during the remainder of its life, free and locomotive, is not only new, but without any parallel in the whole range of the organized part of the creation. No wonder, then, that any naturalist, on the first discovery of the young animal in its first or fixed stage of existence, should consider it as belonging exclusively to those which are known to be permanently fixed; analogy would permit no other conclusion to be formed, and consequently it could be classed with none other except the Crinoideæ, one known genus of which tribe participates with *Comatula* in being locomotive in its advanced stage; so that this circumstance connects all these animals into an inseparable group, with which the present state of our knowledge will not permit us to associate any other of the Asteriæ.

Fig. 19.

Figure 19. Adult *Comatula decanemos.*

"When, therefore, I formerly described the young of the *Comatula** as a new species of *Pentacrinus*, no person could have suspected so anomalous and unexpected a result, as that it was the young state of this curious star-fish, an animal not only free, but leading the most vagrant life of any of the tribe with which it has hitherto been associated by naturalists,—at one time crawling about amongst submarine plants, at others floating to and fro, adhering to thin fragments by means of its dorsal claspers, or even swimming about after the

* Memoir on *Pentacrinus europæus.* Cork, 1827.

manner of the *Medusæ.* In swimming, the movements of the arms of the *Comatulæ* exactly resemble the alternating strokes given by the *Medusæ* to the liquid element, and have the same effect, causing the animal to raise itself from the bottom, and to advance, back foremost, even more rapidly than the *Medusa.* Fig. 19 represents a *Comatula,* after having delivered its stroke to the water.

"The evidence of *Pentacrinus* being the young of *Comatula,* rests upon a comparison of the individuals figured,—20, 21, and 22, 23,—the former being an advanced *Pentacrinus* just beginning to form pinnæ, and the latter the youngest *Comatula* ever taken by dredging. In the *Pentacrinus,* it is to be observed that the arms are just beginning to form pinnæ towards their extremities, that they have the sulphur-yellow color and dark marginal spotting observable in the other, which shews, in like manner, that the upper pinnæ are first formed ; here, figs. 22, 23, we have about three pairs of pinnæ, with two intervening articulations of the arm between each, then three articuli (counting from the apex downwards), and an additional pair of pinnæ just beginning to sprout. From this to the base of the arm are five more articuli, as yet without any pinnæ, the base of each arm on either side presenting one long pinna appropriated to the service of the mouth. On turning the animal over, the dorsal cirri are found to have increased from five to nine, several of them presenting the appearance of recent formation. Individuals a little older are comparatively common, in which the pinnæ are complete, and from this period they appear to form regularly at the apex of the arm, as this goes on extending in length. These small *Comatulæ* still retain the original sulphur-yellow color towards the apices of the arms, the lower part and body assuming the characteristic red of the adult *Comatula.* From observations repeatedly made, I think it most probable that the Comatulæ attain their full growth in one year, so as to be in a condition to propagate their kind the summer following that of their birth. At that time (viz., May and June,) these full grown individuals have the membranous expansion inside each of the pinnæ considerably extended, at least as far as the fifteenth or twentieth pair; these, which are the matrices or conceptacula, at length shew themselves distended with the ova, which in July, and even earlier, make their exit through a round aperture on the fascial side of each conceptaculum, still, however, adhering together in a roundish cluster of about a hundred each, by means of the extension and connection of their umbilical cords. By what means these ova are dispersed, or how they become attached to the stems and branches of corallines, remains

to be discovered; but it is strongly to be suspected that the animal is gifted with the power of placing them in appropriate situations, otherwise we should find them indiscriminately on fuci, shells, stones, etc., which does not appear to be the case. However this may be, if we are allowed to assume that the *Pentacrinus europæus* is the young of *Comatula*, we first perceive the dispersed and attached ova in the form of a flattened oval disk, by which it is permanently fixed to the spot selected, giving exit to an obscurely-jointed stem, ending in a club-shaped head, as in fig. 25, *e*, in which individual the animal is sufficiently advanced to shew the incipient formation of the arms and the mouth with its tentacula, by means of which it obtains the food

Fig. 22.

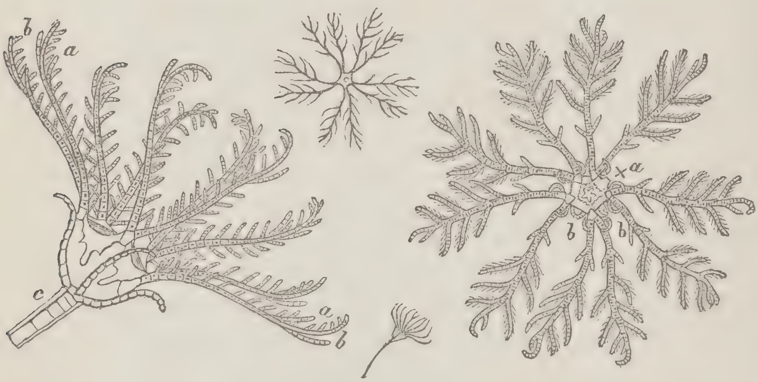

Fig. 21. Fig. 20. Fig. 23.

Figures 20 and 21. An individual of the natural size, and magnified, still more developed than 25, *e*, beginning to form pinnæ towards the ends of the arms, as at *a*, *b*; in this the cirri or claspers at the back of the animal are very distinctly seen.

Figures 22 and 23. A very young *Comatula* of the natural size, and magnified; ×*a*, the vent, in front is the star-like mouth; *b*, *b*, two of the dorsal cirri.

necessary to its successive growth. At *d* of the same figure is another, somewhat more advanced, in which all the ossicula of the arms are obvious, as far as the bifurcation. At the letters *a*, *b*, and *c*, are represented what I considered formerly as completely formed *Pentacrini*, (*a*) from the position shewing the valvular mouth, and (×) the anal aperture: (*b*) shews most clearly the cirri or claspers at the top of the stem, and (*c*) that the living principle extend throughout the entire fabric demonstrated by the varied *movements* of the pedicle. At a later period I observed individuals shewing a still higher degree of

development, figure 21, and in which the arms had the appearance of bifurcating twice towards their extreme ends, and had become of a sulphur-yellow color, with a zone of dark colored spots along either margin.

"Another circumstance confirmatory of these being the young of *Comatula* is derived from these *Pentacrini* being first seen about the time of the dispersion of the ova of the *Comatulæ*, and again entirely disappearing in September, the only season when young *Comatulæ* are to be obtained, and such as are represented in figs. 22, 23. In these

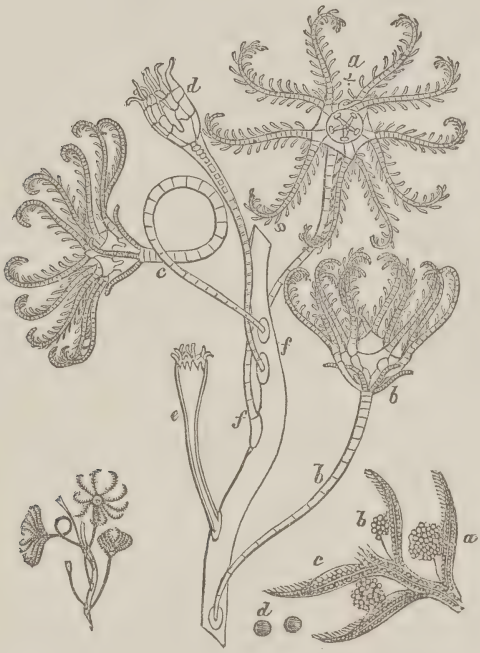

Fig. 24. Fig. 25. Fig. 26.

Figure 24. *Pentacrinus europæus.* A group, natural size.
" 25. The same, magnified; *f*, the basis; *e* and *d*, two individuals in early stages of growth; *a*, *b*, *c*, fully developed individuals; at +, letter *a*, the anus is seen, and below it the mouth of the animal.
" 26. Part of one of the arms seen in face; *a*, ova protruding from the conceptacula; *b*, ova just beginning to make their exit; *c*, one as yet filled wlth the ova; *d*, ova magnified.

the points of resemblance to advanced *Pentacrini* have been already alluded to, and it is quite evident, that since they became detached, pinnæ must have been added in both directions, both towards the

apex and downwards towards the base of the arms. These specimens which have made a further progress are plentiful, and have all the pinnæ complete down to the bifurcation, with a few additional claspers added at the back. At figure 19, a middle-sized *Comatula decanemos* is given, as they appear in June when pregnant with ova; and at fig. 26 is a portion of an arm magnified, with the ova beginning to escape from the conceptacula, which they do successively from the base upwards. Mr. Millar, in his labored but excellent work on the Crinoideæ, has figured our *Comatula* in this stage as a new species, under the title of *C. fimbriata;* indeed, no naturalist who had not investigated their habitudes in their own element, and at all seasons, could possibly arrive at the knowledge of this very remarkable and curious piece of economy, which may be considered as unique. These animals are further distinguished by the peculiarity of having two openings to the intestinal canal, by which they also differ from the rest of the Asteriæ.

"The great abundance of *Comatulæ*, in the places they inhabit, is not to be wondered at when we are aware how exceedingly prolific they are; thus each arm may be estimated to bear thirty fruitful conceptacles, each producing about a hundred ova, and as there are ten such, this gives 30,000! as the amount of ova produced by a single individual."

DECADE 4. PL.1
LOWER SILURIAN
(Chazy)

GEOLOGICAL SURVEY OF CANADA.

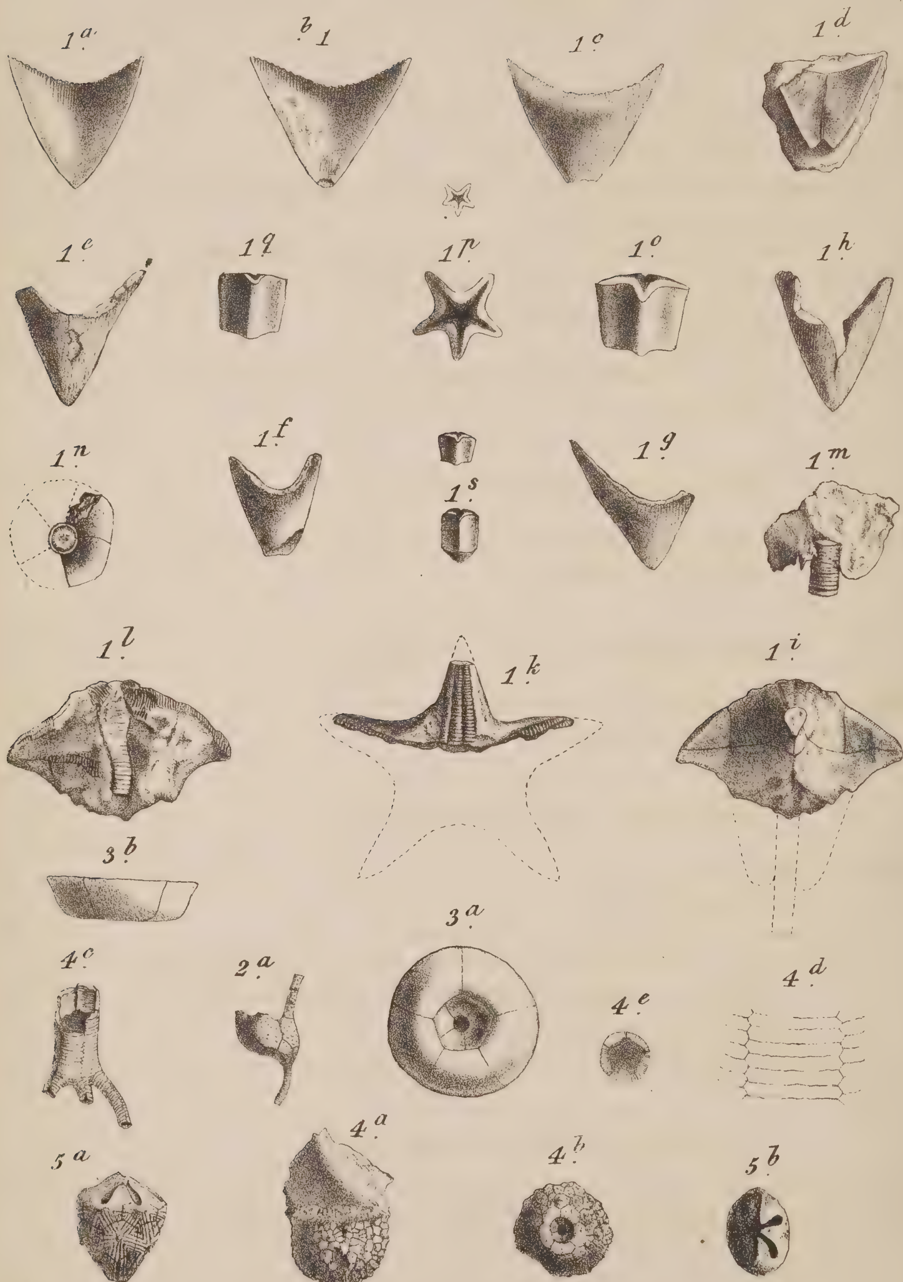

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PLATE 1.

Blastoidocrinus carchariædens (page 18).

Figure 1*a*–1*h*. Deltoid plates of *B. carchariædens*.
" 1*i*. Side view of a specimen which has three of the rays partly preserved.
" 1*k*. The same, seen from above.
" 1*l*. Vertical section, shewing the position of the column in the interior.
" 1*m*. Fragment of the base, shewing the manner in which the column penetrates into the visceral cavity.
" 1*n*. Under side of 1*m*.
" 1*o*–1*s*. Small pentagonal crinoidal remains found associated with *B. carchariædens*.

Hybocrinus pristinus (page 23).

Figure 2*a*. Left side of a specimen which retains a portion of the column and part of one of the arms.

Pachyocrinus crassibasalis (page 22).

Figure 3*a*. View of the base of the only specimen collected.
" 3*b*. Side view of the same.

Rhodocrinus asperatus (page 27).

Figure 4*a*. Side view of a specimen.
" 4*b*. View of the base.
" 4*c*. A radix found in the same slab along with 4*a*.
" 4*d*. Portion of the surface of 4*c*, magnified. The joints of this column appear to be composed near the root of five pieces each, which interlock, as represented in the figure 4*d*.
" 4*e*. Transverse section of the column near the root.

Palæocrinus striatus (page 25).

Figure 5*a*. Posterior side of a nearly perfect specimen.
" 5*b*. Summit of the same, shewing the ambulacral orifices and grooves.

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PLATE II.

Hybocrinus tumidus (page 28).

Figure 1*a*. View of the anterior side of a specimen, shewing the azygos plates.
" 1*b*–1*d*. Different views of other specimens.
" 1*e*. A polished transverse section just below the base of the arms, shewing the channels in the primary radial plates for the ambulacral orifices.

Hybocrinus conicus (page 29).

Figure 2*a*. Right side of a specimen of the average size.
" 2*b*. Left side of another specimen.

Carabocrinus radiatus (page 31).

Figure 3*a*. View of the anterior side, shewing the azygos inter-radius.
" 3*b*. Base of the same specimen.
" 3*c*. Posterior side of a different specimen.
" 3*d*. Ventral surface of a small individual. In the centre of the lower side of the figure is the mouth, and directly above it the small anal aperture.
" 3*e*. Ventral surface of a larger specimen, shewing obscurely the five ambulacral grooves. The three round darkly-shaded spots appear to be apertures accidentally produced.

Carabocrinus Vancortlandti (page 32).

Figure 4 represents the posterior side of the specimen.

Porocrinus conicus (page 34).

Figures 5*a*, 5*b*. Posterior views of two specimens.
" 5*c*. Anterior side of a specimen, enlarged to shew the azygos plates and poriferous areas.
" 5*d*. Ventral surface of 5*a*.

DECADE 4 Pl. 3.
LOWER SILURIAN
Trenton.)

GEOLOGICAL SURVEY OF CANADA.

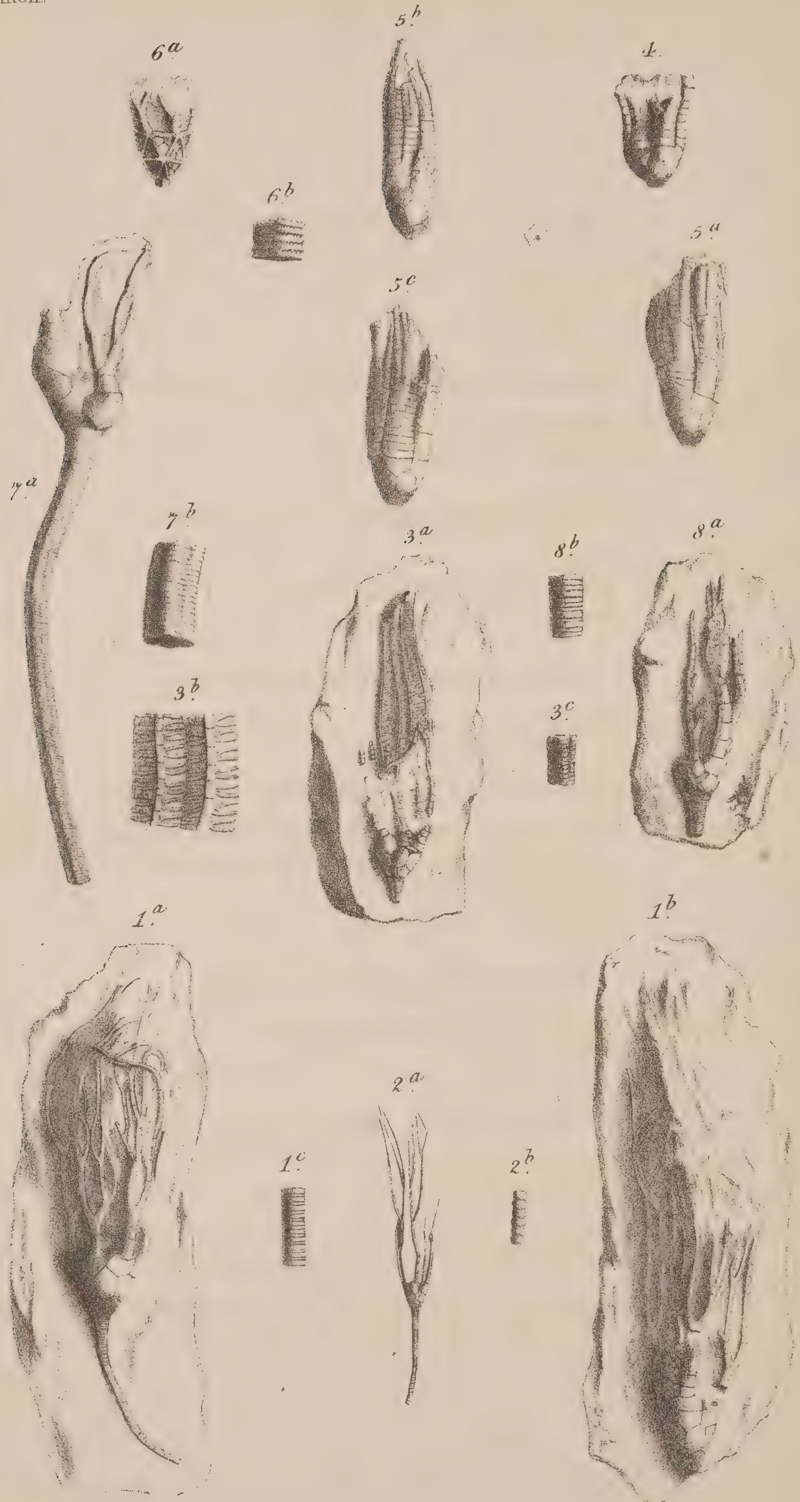

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PLATE III.

Dendrocrinus gregarius (page 36).

Figure 1*a*. Posterior view of a specimen.
" 1*b*. The left side.
" 1*c*. Column, enlarged.

Dendrocrinus acutidactylus (page 37).

Figure 2*a*. Posterior side of a specimen.
" 2*b*. Portion of the column, enlarged.

Dendrocrinus proboscidiatus (page 38).

Figure 3*a*. Anterior side.
" 3*b*. Part of surface of proboscis, enlarged.
" 3*c*. Portion of column, enlarged.

Dendrocrinus humilis (page 39).

Figure 4. The only specimen discovered ; posterior side.

Dendrocrinus latibrachiatus (page 39).

Figure 5*a*. View of the left side, shewing the left anterior ray, which has the first and second primary radials included in the cup.
" 5*b*. View of the anterior side.
" 5*c*. The posterior side.

Palæocrinus angulatus (page 45).

Figure 6*a*. Left side of the only specimen discovered.
" 6*b*. Column, enlarged.

Dendrocrinus rusticus (page 41).

Figure 7*a*. A specimen very imperfect.
" 7*b*. A small portion of the column, enlarged.

Dendrocrinus cylindricus (page 44).

Figure 8*a*. Anterior side of *D. cylindricus*. That which appears to be a large arm near the left side is the proboscis.
" 8*b*. Part of the column, a little enlarged.

LOWER SILURIAN
(Trenton.)

GEOLOGICAL SURVEY OF CANADA.

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PLATE IV.

DENDROCRINUS CONJUGANS (page 41).

Figure 1*a*. Anterior side.
" 1*b*. Column, a little enlarged.
" 2*a*. Side view of a specimen.
" 2*b*. Column of same, enlarged.

LECANOCRINUS LÆVIS (page 47).

Figure 3*a*. A slightly crushed specimen.

LECANOCRINUS ELEGANS (page 47).

Figure 4*a*. A specimen shewing one of the hexagonal basal plates.
" 4*b*. Several joints of the column, a little enlarged.

HETEROCRINUS CANADENSIS (page 48).

Figure 5*a*. A specimen with part of the column attached.
" 5*b*. Portion of the column, enlarged.
" 5*c*. Anterior side of a different specimen.
" 5*d*. A specimen which has the pinnulæ preserved.

HETEROCRINUS TENUIS (page 50).

Figure 6*a*. A specimen with part of the column.
" 6*b*. A few joints of the column, enlarged.
[See also Plate X.]

HETEROCRINUS INÆQUALIS (page 51).

Figure 7*a*. A nearly perfect specimen, but so deeply embedded in stone that only one side can be seen.

HETEROCRINUS ARTICULOSIS (page 51).

Figure 8. One of the rays of this species.

DECADE 4. Pl. 5.
LOWER SILURIAN
(Trenton)

GEOLOGICAL SURVEY OF CANADA.

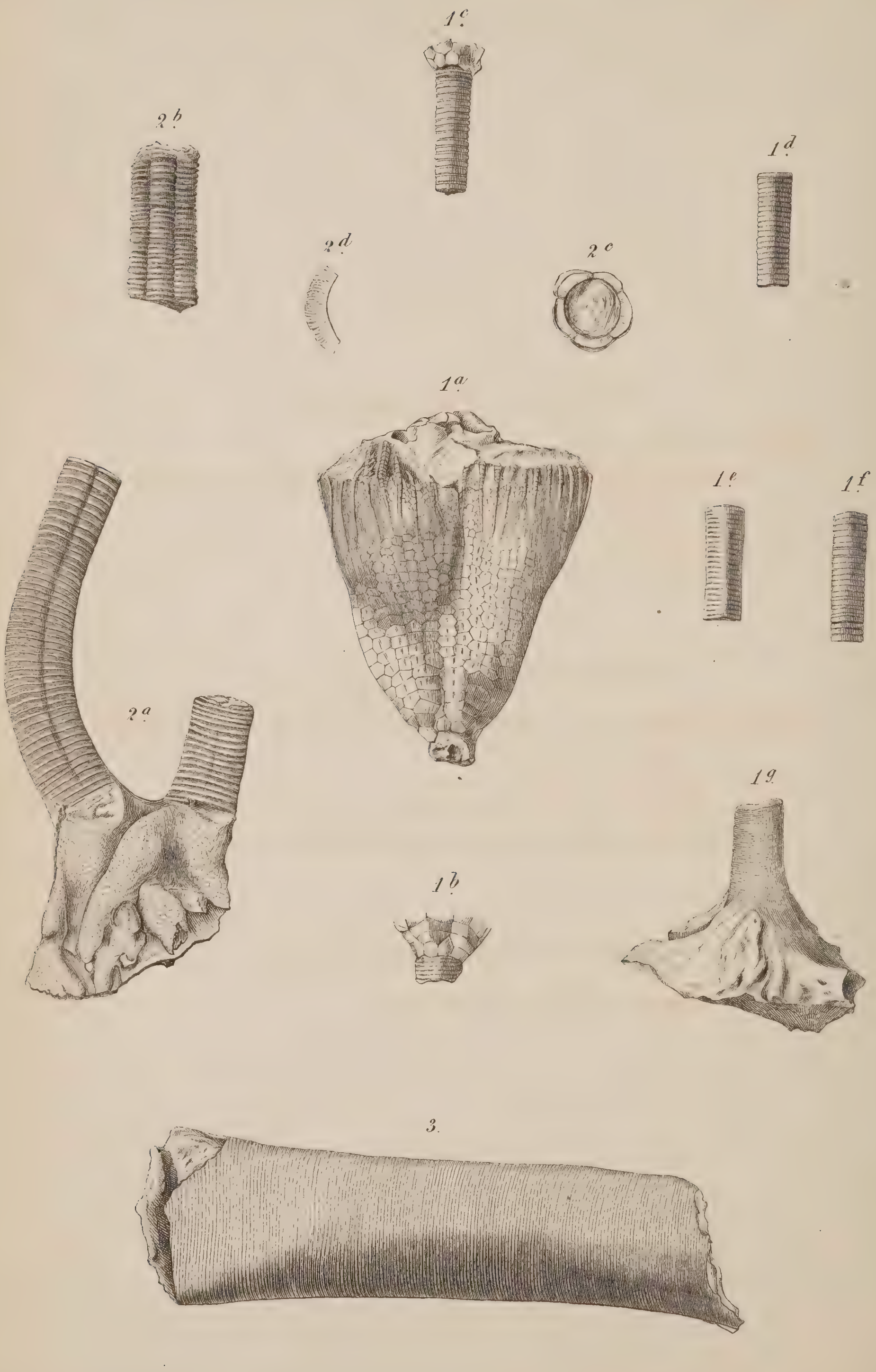

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PLATE V.

Cleiocrinus regius (page 53).

Figure 1*a*. A nearly perfect cup of this species.

" 1*b*. The base, shewing the small basal plates, with the quadrangular first primary radials between them.

" 1*c*, 1*d*, 1*e*, and 1*f*. Fragments of the column.

" 1*g*. The base of the column.

Cleiocrinus grandis (page 54).

Figure 2*a*. Portions of two individuals of this species, which appear to have grown upon the same spot.

" 2*b*. Fragment of a column, crushed.

" 2*c*. Transverse section, shewing the large alimentary canal.

[This species occurs also at Montreal, in the Trenton limestone.)

Cleiocrinus magnificus (page 54).

Figure 3. Fragment of the column of this species.

DECADE 4. Pl. 6.
LOWER SILURIAN
(Trenton.)

GEOLOGICAL SURVEY OF CANADA.

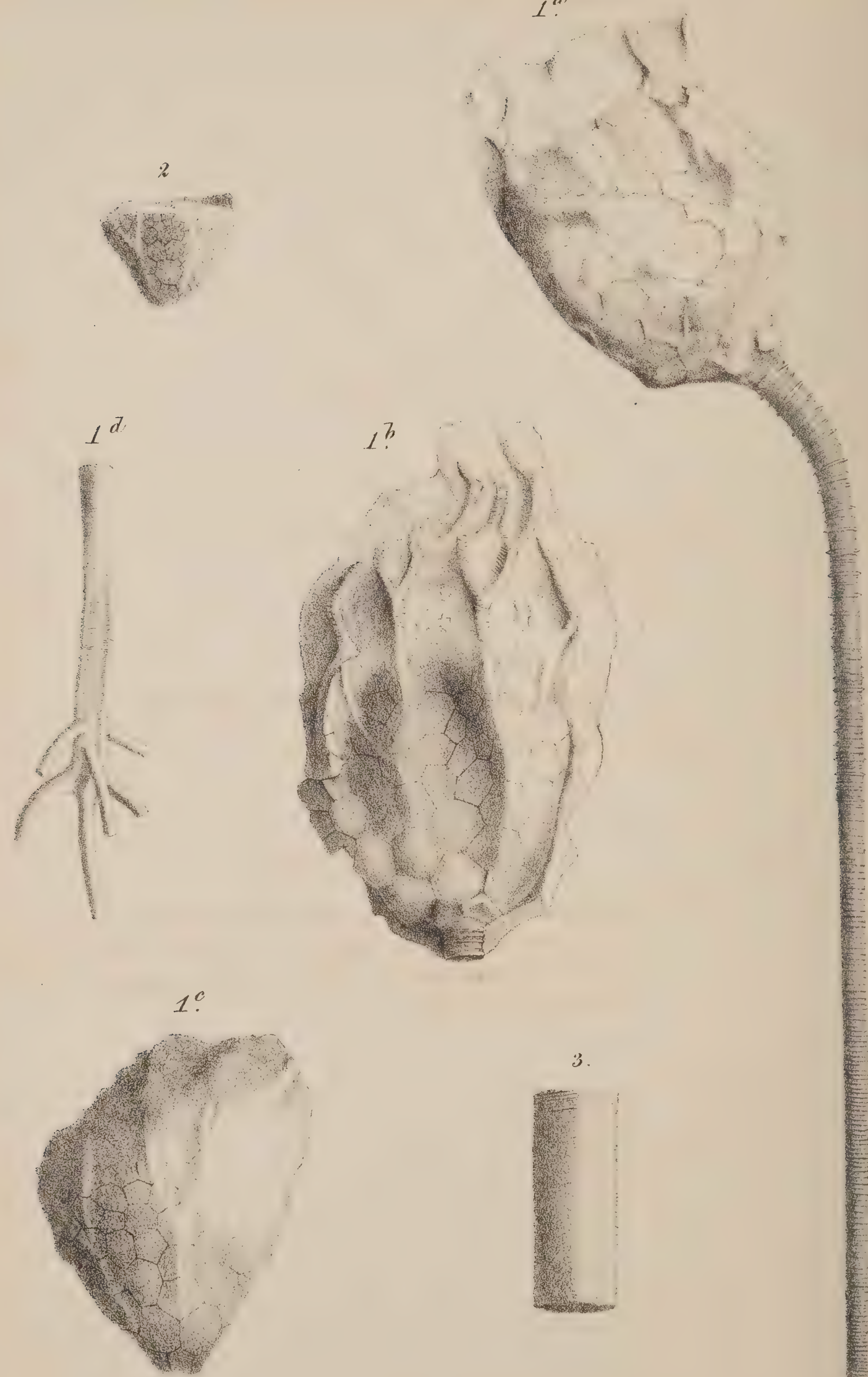

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PLATE VI.

RHODOCRINUS PYRIFORMIS (page 61).

Figure 1*a*. A specimen with part of the column attached.
" 1*b*, 1*c*. Crushed specimens.
" 1*d*. The radix of this species.

RHODOCRINUS MICROBASALIS (page 63).

Figure 2. An imperfect specimen of this species.

RHODOCRINUS GIGAS.

Figure 3 is a fragment of the column of a large *Rhodocrinus* which occurs in the upper part of the Trenton limestone, at the City of Ottawa. I have not seen the cup, but as the columns are easily recognizable, I propose the above name for them.

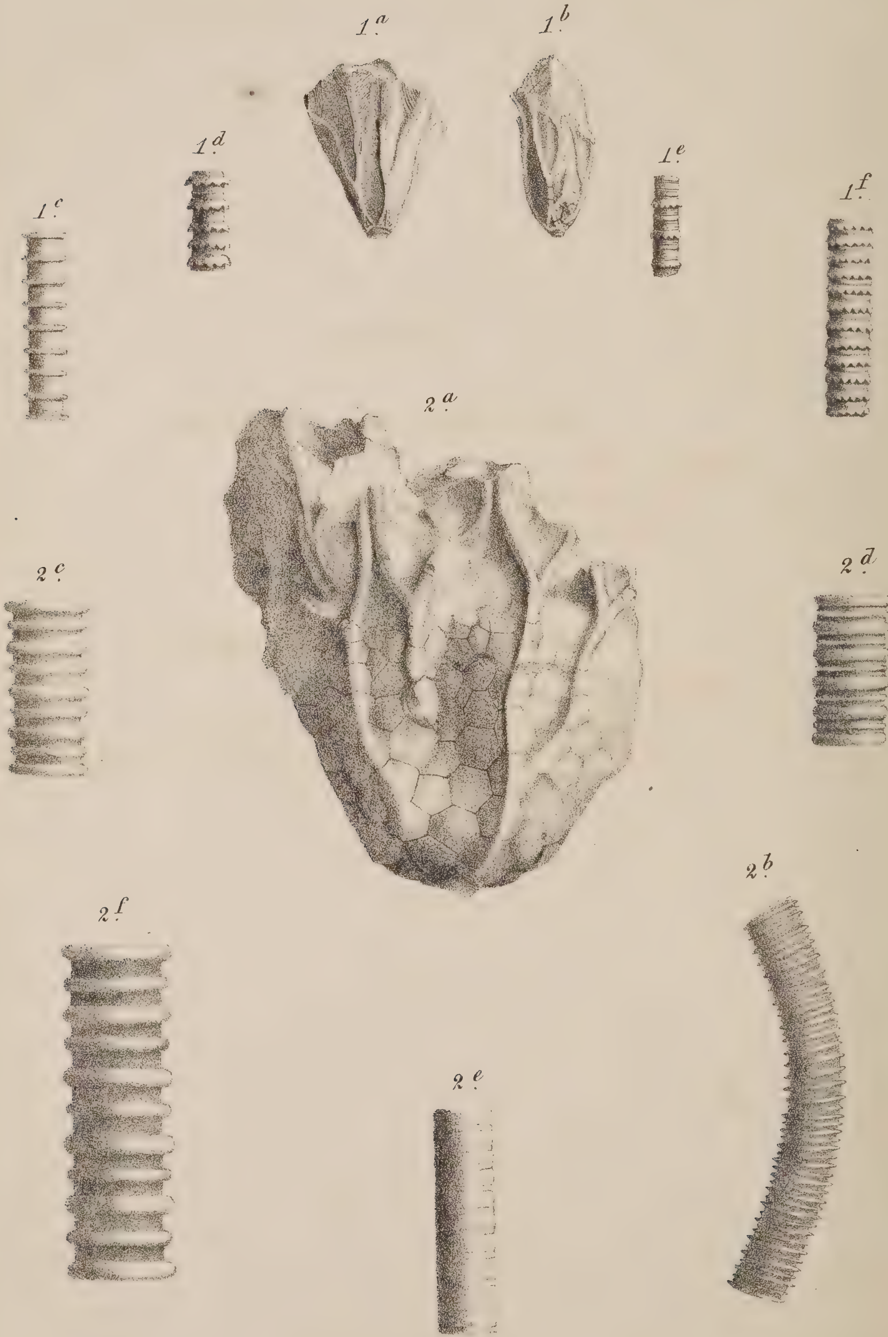

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PLATE VII.

Glyptocrinus priscus (page 56).

Figure 1*a*. View of the posterior side of *G. priscus*.
" 1*b*. Anterior side of the same specimen.
" 1*c*, 1*d*, 1*e*, 1*f*. Columns found associated with 1*a*.

Glyptocrinus ramulosus (page 57).

Figure 2*a*. A cup of medium size.
" 2*b*. Portion of the column near the base of the cup.
" 2*c*–2*f*. These figures represent different parts of a very long column.

[See also Plate VIII.]

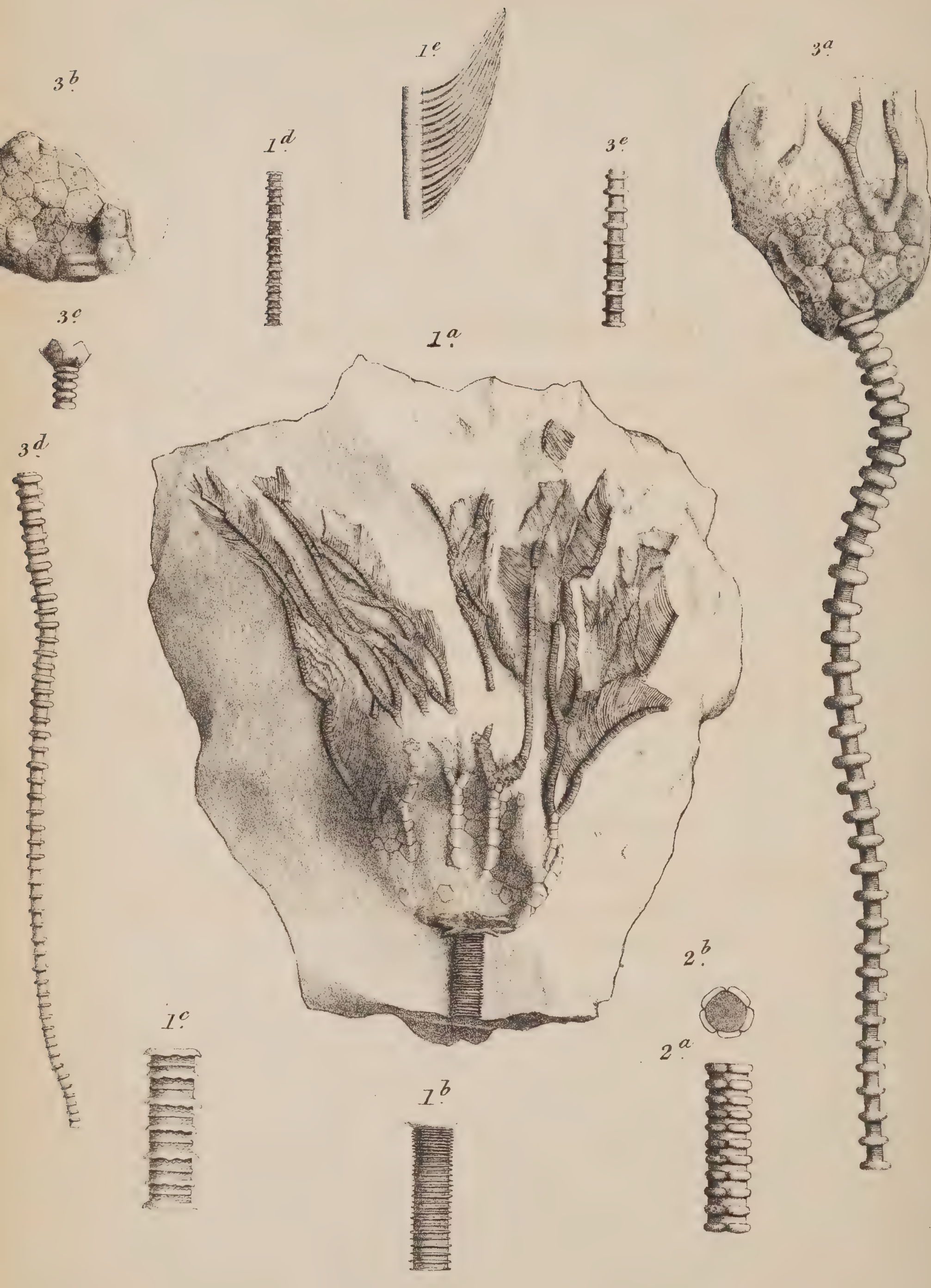

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PLATE VIII.

GLYPTOCRINUS RAMULOSUS (page 57).

Figure 1*a*. A crushed specimen, with part of the column attached.
" 1*b*. The column of 1*a*, enlarged.
" 1*c*, 1*d*. Columns found along with 1*a*.
" 1*e*. A portion of one of the arms, enlarged.

[See also Plate VII.]

GLYPTOCRINUS LACUNOSUS (page 61).

Figure 3*a*. A specimen with part of the column attached.
" 3*b*. Fragment of a different specimen.
" 3*c*, 3*d*, 3*e*. Columns of this species.

GLYPTOCRINUS QUINQUEPARTITUS.

Figure 4*a*–4*b*. Columns such as the specimen represented by these figures are not uncommon in the upper part of the Trenton limestone, at the City of Ottawa.

DECADE 4. Pl. 9.
LOWER SILURIAN
(Trenton.)

GEOLOGICAL SURVEY OF CANADA.

Horace Smith. Del.

G. Matthews. Montreal.

PLATE IX.

GLYPTOCRINUS MARGINATUS (page 59).

Figure 1*a*. The only specimen collected. The part well exposed (represented in the right side of the figure) is the azygos inter-radius.

GLYPTOCRINUS ORNATUS (page 60).

Figure 2*a*. Anterior side of a specimen of *G. ornatus*.

RETEOCRINUS FIMBRIATUS (page 65).

Figure 3*a*. The only specimen discovered.
" 3*b*. The base, enlarged; the unshaded pentagonal space shews the form of the upper joint of the column.
" 3*c*. One of the arms, with some of the pinnulæ attached, enlarged.

RETEOCRINUS STELLARIS (page 64).

Figure 4*a*. View of the anterior side of a specimen.
" 4*b*. A specimen retaining a piece of the column.
" 4*c*. Several of the joints enlarged. They appear to be nearly equal in size, and sharp-edged at the base of the cup.
" 4*d*, 4*e*. Fragments of this species.

[In 4*a* and 4*e* the small stellate plates between the arms are represented.]

DECADE 4. PL. 10
LOWER SILURIAN
(Trenton & Hudson River)

GEOLOGICAL SURVEY OF CANADA

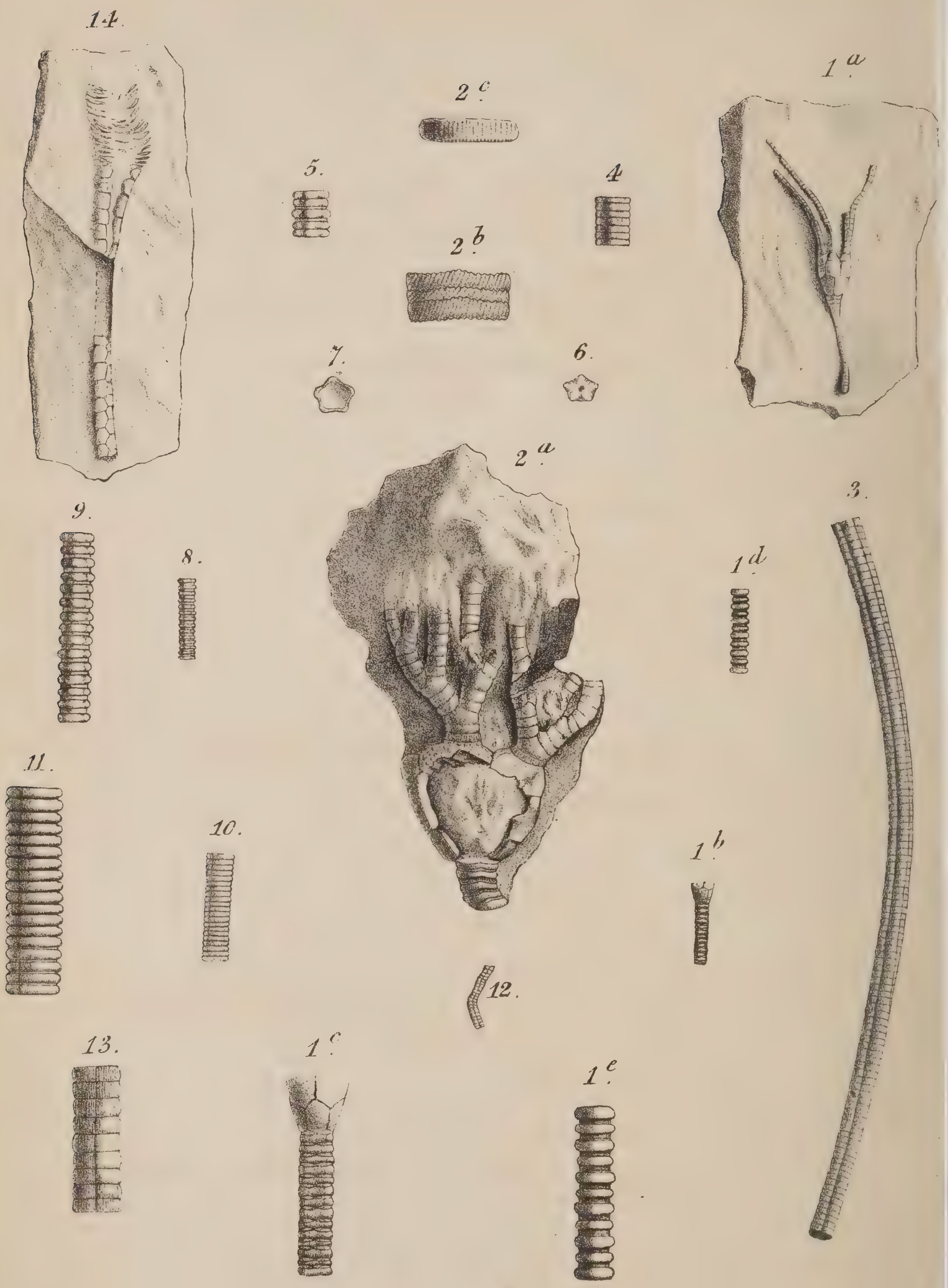

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PLATE X.

Heterocrinus tenuis (page 50).

Figure 1*a*. *Heterocrinus tenuis*, from the Trenton limestone, near the City of Montreal.

" 1*b*. Part of column and base of another specimen on same slab.

" 1*c*. Enlargement of 1*b*.

" 1*d*, 1*e*. Other fragments on the same slab of stone.

[See also Plate IV.]

Carabocrinus tuberculatus (page 33).

Figure 2*a*. The only specimen collected.

" 2*b*. Three joints of the column, enlarged.

" 2*c*. One of the joints of the arms, enlarged.

Syringocrinus paradoxicus (page 65).

Figure 14. A specimen collected at Beauport.

COLUMNS OF UNDETERMINED GENUS.

Figure 3. A quinquepartite column from the Trenton limestone, City of Ottawa.

" 4–7. Fragments from Hudson River group, Point William, Lake Huron.

" 8. From Trenton limestone, Montreal.

" 9. The same, enlarged.

" 10. From the Hudson River group, Anticosti.

" 11. The same, enlarged.

" 12. A small striated column from the Trenton limestone, City of Montreal.

" 13. The same, enlarged.